REPORT

OF THE

GEOLOGICAL SURVEY OF OHIO.

VOLUME I.

GEOLOGY AND PALEONTOLOGY.

PART I. GEOLOGY.

OFFICERS OF THE SURVEY.

J. S. NEWBERRY, ...	CHIEF GEOLOGIST.
EDWARD ORTON, ...	ASSISTANT GEOLOGIST.
E. B. ANDREWS, ...	ASSISTANT GEOLOGIST.
T. G. WORMLEY, ...	CHEMIST.
F. B. MEEK, ...	PALEONTOLOGIST.

PUBLISHED BY AUTHORITY OF THE LEGISLATURE OF OHIO.

COLUMBUS, OHIO:
NEVINS & MYERS, STATE PRINTERS.
1873.

ERRATA.

Page 17, line 32,		for Arkansan	read Arkansaw.
" 24, " 6	from bottom,	" continual	" continued.
" 26, " 28,		" waters	" watershed.
" 29, " 1,		" firmness	" fineness.
" 31, " 3	from bottom,	" I. G. Cooper	" J. G. Cooper.
" 32, " 2,		" 36,964	" 39,964.
" 32, " 21,		" its	" it.
" 39, " 8	from bottom,	" cannot	" can not.
" 42, " 13	" "	" A. Y. & R. R. R.	" A. Y. & P. R. R.
" 48, " 9,		" Contribution	" Contributions.
" 48, " 19,		" bank	" banks.
" 72, " 24,		" the Conglomerate	" (the Conglomerate).
" 78, " 18,		" records	" record.
" 80, " 3	and 21,	" *period*	" *System.*
" 82, " 18,		after California	add Nevada, Utah.
" 99, " 22,		for Christie	read Christy.
" 103, " 5,		" of	" from.
" 107, " 29,		" date	" dates.
" 125, " last,		" Mr. Meek	" Prof. Orton.
" 148, " 22,		" Delphos	" Charloe.
" 149, " 6,		" *Euompholus*	" *Euomphalus.*
" 162, " 27,		" icy	" ice.
" 163, " 26,		" limestones	" limestone.
" 165, " 15,		" , however	" , therefpre.
" 249, " 16,		" seems	" seams.
" 252, " 11,		" serm	" seam.
" 262, " 20,		" elveations	" elevations.
" 347, " 22,		" Bischoff	" Bischof.
" 347, bottom line,		" Bischoff	" Bischof.
" 366, line 20,		" S. F. Miller	" S. A. Miller.
" 383, " 6,		" Hall	" Say.
" 387, " 32,		" gems	" genus.

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MEMBERS OF THE GEOLOGICAL BOARD.

HIS EXCELLENCY EDWARD F. NOYES, . . .	GOVERNOR OF OHIO.
HON. ISAAC WELSH, ...	TREASURER OF STATE.
HON. T. W. HARVEY, ...	SUP. COM. SCHOOLS.

MEMBERS OF THE GEOLOGICAL CORPS.

1869—1872.

J. S. NEWBERRY, ...	CHIEF GEOLOGIST.
EDWARD ORTON, ...	ASSISTANT GEOLOGIST.
E. B. ANDREWS, ...	ASSISTANT GEOLOGIST.
J. H. KLIPPART, ...	ASSISTANT GEOLOGIST.
T. G. WORMLEY, ...	CHEMIST.
F. B. MEEK, ...	PALEONTOLOGIST.

LOCAL AND VOLUNTEER ASSISTANTS.

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G. K. GILBERT,
W. B. GILBERT,
S. A. GOLDSCMIDT,
OGDEN HAIGHT,
REV. H. HERTZER,
F. C. HILL,
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H. M. SMITH,
J. J. STEVENSON,
ROBERT WARDER,
A. W. WHEAT,
H. A. WHITING,
N. H. WINCHELL.

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VOL. I.—PART I.

SECTION I.

THE GENERAL GEOLOGICAL RELATIONS AND STRUCTURE OF OHIO.

GEOLOGY OF OHIO.

CHAPTER I.

HISTORICAL SKETCH.

The first information obtained by the citizens of Ohio in regard to the geological structure and mineral resources of the State, was derived from the report of a committee appointed under a resolution of the Legislature, passed the 14th day of March, 1836, "To report to the next Legislature the best method of obtaining a complete geological survey of the State, and an estimate of the probable cost of the same." This committee consisted of Dr. S. P. Hildreth, chairman, Dr. John Locke, Prof. J. H. Riddell, and Mr. I. A. Lapham.

In the execution of the task assigned to this committee, geological reconnoissances were made during the succeeding summer, of the Coal Measures of South Eastern Ohio, by Dr. Hildreth, and of the western and northern portions of the State, by Prof. Riddell and Mr. Lapham; while chemical analyses of various iron ores and limestones were made by Dr. Locke. The observations and conclusions of this committee were embodied in reports from all the members, which reports were submitted to the Legislature at their succeeding session, and were published by State authority. At this time the science of geology had nowhere attained anything like its present perfection, and very little was known by any one in regard to the structure of our country. The geological survey of New York was then in progress, but the splendid results accomplished by it had not yet been announced. As a consequence, the gentlemen who formed this committee prosecuted their investigations, not only in an untried field, but with little that could serve to guide them in observations made elsewhere by other geologists. At that time almost nothing was

known of palaeontology in this country. No one had learned what are the characteristic fossils of our formations, and, consequently, the relative positions of the different strata met with were to be painfully worked out by a careful examination of the rare exposures of their lines of contact. It was not easy, nor even possible, in all instances, to identify any of the formations by their lithological characters alone, for these are proverbially unreliable, and they are often found to change completely in going from county to county. It is now well understood, not only that fossils are safe and convenient guides in studying the relations and distribution of fossiliferous rocks, but that their assistance is indispensable, and that no conclusions can be regarded as accurate and trustworthy unless confirmed by their evidence. The well-read palaeontologist finds in every characteristic fossil an infallible record of the age of the rock that contains it, so that, when he can read the language, the fossiliferous rocks are all ticketed to his hand. Nothing can better illustrate the truth of these statements than the laborious and painful efforts of our pioneer geologists to determine, without palaeontological data, the age and relations of our formations. After spending a summer in the study of a group of limestones which underlie the western part of the State, Dr. Riddell, with considerable hesitation and diffidence, announces the opinion that the blue limestone of Cincinnati underlies and is older than the buff limestone of Columbus. Even two years afterward, when the Geological Board, subsequently created, had devoted two seasons of field work to the study of our geology, the exact geological ages of these formations were still undecided.

Much valuable information was, however, contained in the reports of the committee on the geological survey, especially in that of Dr. Hildreth, where the first glimpse was given to the public of the structure and richness of the southern iron district—lying between Marietta and Portsmouth—where the Coal Measure ores exhibit a development equalled in no other part of our country, and where the iron industry of Ohio has, till lately, been mainly centered.

In obedience to their instructions, the committee submitted a plan for a general geological survey of the State, with an estimate of the necessary expenditure. The Legislature of 1836–37 at once acted on the recommendation of the committee, and passed a bill on the 27th of March, 1837, providing for a geological survey, appointing a corps of geologists, and voting an appropriation of $12,000 for the prosecution of the work during one year.

The Board then organized consisted of the following members:

W. W. Mather, State Geologist.
Dr. S. P. Hildreth,
Dr. John Locke,
Prof. J. P. Kirtland,
J. W. Foster,
Charles Whittlesey,
C. Briggs, Jr.,
} Assistants.

These gentlemen entered upon their duties during the following spring, and the results of their summer's work were embodied in the "First Annual Report on the Geology of Ohio," (8vo. pp. 134) presented to the Legislature at the ensuing session, and immediately published.

This report includes records of geological reconnoissances by Prof. Mather, Dr. Hildreth and Mr. Briggs, and preliminary reports on zoology by Prof. Kirtland, and on topography by Col. Whittlesey. Prof. Locke, having spent the summer in Europe, took no part in the geological work of the corps during the first year, and made no report.

In the succeeding summer the work of the Geological Survey was continued under the same organization. The observations made during this season were presented, and published in a report of 286 8vo. pages, entitled "The Second Annual Report of the Geological Survey of the State of Ohio, Columbus, Ohio, 1837." This volume includes reports of W. W. Mather, pp. 30, Col. Whittlesey, pp. 32, Mr. Foster, pp. 36, Prof. Briggs, pp. 47, Prof. Kirtland, pp. 46, and Dr. Locke, pp. 86; and contains much valuable information in regard to the geological structure and mineral resources of the State.

In consequence of the financial panic of 1837, and the paralysis of business that followed, it was considered necessary to diminish in every possible way the public expenditure, and, accordingly, the Legislature of 1838–39 made no appropriation for the continuation of the Geological Survey, and it was at once suspended. However plausible the arguments in favor of such a step may have appeared, there are comparatively few of our citizens who do not feel that it was dictated by a short-sighted policy. The benefit derived by the State from the geological reconnoissance—for it was little more—made by the State Board, conclusively demonstrated that the Geological Survey was a producer and not a consumer; that it added far more than it took from the public treasury, and therefore deserved special encouragement and support, as a wealth-producing agency, in our darkest financial hour.

By the arrest of the work of the Geological Corps, the development of our mineral resources was not entirely stopped, but it was greatly

retarded and thrown from public into private hands. During the thirty years that elapsed before a new Geological Survey was organized, much was done by private parties in the investigation of the geology and economic value of certain tracts and districts of the State. Careful surveys of mining properties, elaborate analyses of coal, iron, &c., &c., were made at private cost, and there is very little doubt that for such investigations, in the long interval of time I have designated, more money was paid than would have sufficed to complete the public survey begun in 1837. All the information thus gained was, however, monopolized by those who paid for it, and instead of enlightening the landholder as to the abundance and value of the minerals his farm or tracts contained, it oftener served the purposes of the speculator only, guiding him in his purchases and placing the farmer quite at his mercy. There are many who think the development of the mineral resources of our State should be altogether left to time and private enterprise; but no one who has watched with any care the progress of events during the last twenty-five years, in this and other States, will have failed to notice that it very rarely happens that the owner of a farm containing coal, iron, clay, or any other useful mineral, will, of his own accord and at his own expense, have any or all his subterranean treasures so far investigated as to learn with accuracy their value. To do this, he must invoke the aid of the geologist and chemist, personages with whom he is not only unacquainted—since they are probably residents of a distant city—but of whose professions he has in all probability only a dim and shadowy idea. He therefore holds his land at its agricultural value, and sells it at such valuation to the first speculator who suspects, tests and then discovers its hidden wealth.

The publication of the reports of the First Geological Board did much to arrest the useless expenditure of money in the search for coal outside of the coal field, and in other mining enterprises equally fallacious, by which, through ignorance of the teachings of geology, parties are constantly led to squander their means. From the tendency which all mining schemes have to excite the imagination, it is scarcely less important to our people to know accurately what we have not, than what we have, among our mineral resources.

During the last twenty years, efforts have been made by members of the Legislature who appreciated the importance of a thorough investigation of our mineral wealth, to have the geological survey resumed. To this end recommendations were made in several of the messages of our Governors, and bills in the Legislature were introduced by Dr. Jewett, Mr. Canfield, Mr. Scott, and by General Garfield. There was no consid-

erable opposition to either bill originating in doubt of the intrinsic merit of the measure, but at one time because the State Treasurer had appropriated to his own uses half a million of the people's money, and subsequently because the treasury was long kept empty by the expenditures upon the State House, it was thought by the majority wiser to defer making appropriations for this, as well as various other confessedly desirable objects, till the finances of the State should be in a better condition. In all these years, however, the State was suffering a positive annual loss, in both its industry and credit, for the want of the knowledge a properly conducted geological survey could not fail to impart. Every financial agent of the State, located in or visiting the moneyed centers of our country or the world; agents going abroad to effect loans with which to construct our lines of railroad, all took pains to gather information in reference to our geology, and all had to deplore the fact that this information was so meagre.

Finally, the great rebellion came upon us with all its horrors, and its waste of life and treasure. For five years all the thoughts and energies of the people were turned to the arts of war, and the arts of peace were well-nigh forgotten. When, however, the struggle was over, and the nation's life, so eagerly sought and strongly imperiled, was saved, our citizen soldiers laid down their arms to return to plow and workshop, and once more the processes of creation and conservation succeeded to those of destruction.

Among the methods suggested for repairing the breaches of war, and moving faster the retarded wheel of progress, was a geological survey; a thorough investigation of the quality, quantity and distribution of each of our mineral staples with a view to the expansion of all the wealth-producing industries based upon them.

This measure was recommended to the Legislature of 1869 in the annual message of Governor Hayes, and was made the subject of a bill introduced in the House of Representatives by Captain Alfred E. Lee, of Delaware county. This bill was subsequently passed in March, 1869, by a large majority, irrespective of party, in both branches, and became a law, of which the following is a copy:

LAW PROVIDING FOR A GEOLOGICAL SURVEY OF OHIO.

SECTION 1. *Be it enacted by the General Assembly of the State of Ohio*, That the governor is hereby required to appoint, by and with the advice and consent of the senate, a chief geologist, who shall be a person of known integrity and competent practical and scientific knowledge of the sciences of geology and mineralogy; and upon consultation with said chief geologist and the like concurrence of the senate, the governor shall appoint one or more suitable assistants, not exceeding three in number, one of

whom shall be a skillful analytical and agricultural chemist, the said chief geologist and assistants to constitute a geological corps, whose duty it shall be to make a complete and thorough geological, agricultural and mineralogical survey of each and every county in the state.

SECTION 2. The said survey shall have for its objects:

1st. An examination of the geological structure of the state, including the dip, magnitude, number, order and relative position of the several strata, their richness in coals, clays, ores, mineral waters and manures, building stone and other useful materials, the value of such materials for economical purposes, and their accessibility for mining or manufacture.

2d. An accurate chemical analysis and classification of the various soils of the state, with the view of discovering the best means of preserving and improving their fertility, and of pointing out the most beneficial and profitable modes of cultivation. Also a careful analysis of the different ores, rocks, peats, marls, clays, salines and all mineral waters within the state.

3d. To ascertain by meteorological observations the local causes which produce variations of climate in the different sections of the state. Also to determine by strict barometrical observations the relative elevation and depression of the different parts of the state.

SECTION 3. It shall be the duty of said chief geologist in the progress of the examinations hereby directed, to collect such specimens of rocks, ores, soils, fossils, organic remains and mineral compounds as will exemplify the geology, mineralogy and agronomy of the state, and shall deposit said specimens, accurately labeled and classified, in a room provided by the state board of agriculture, to be carefully preserved under the supervision of said board.

SECTION 4. It shall be the duty of the chief geologist, on or before the first Monday in January of each year, during the time occupied in said survey, to make a report to the governor of the results and progress of the survey, accompanied by such maps, profiles and drawings as may be necessary to exemplify the same, which reports the governor shall lay before the general assembly.

SECTION 5. When the said survey shall be fully completed, the chief geologist shall make to the governor a final report, including the results of the entire survey, accompanied by such drawings and topographical maps as may be necessary to illustrate the same, and by a single geological map, showing by colors and other appropriate means the stratification of the rocks, the character of the soil, the localities of the beds of mineral deposits, and the character and extent of the different geological formations.

SECTION 6. The annual appropriations which may be made by the general assembly for carrying out this act, shall be expended under the direction of the governor upon the certificate of the chief geologist, approved by the governor, and the warrant of the auditor of state, as follows:

For salary of chief geologist, three thousand dollars.

For salaries of assistants, not more than eighteen hundred dollars each.

For chemicals, five hundred dollars.

For contingent expenses of the survey, including actual traveling expenses of geological corps and hire of local assistants, five thousand dollars.

SECTION. 7. No money shall be paid for the purposes of said survey until the chief

geologist and his assistants shall have entered upon the discharge of their duties as prescribed by this act.

SECTION 8. The survey shall be commenced by the first of June next, or as soon thereafter as practicable, and shall be completed within three years from and after the time of its commencement.

SECTION 9. This act shall take effect and be in force from and after its passage.

In the performance of the duty assigned to him by this act of the Legislature, the Governor nominated the following persons members of the Geological Corps; and these nominations were confirmed by the Senate:

J. S. Newberry, Chief Geologist.
E. B. Andrews,
Edward Orton,
John H. Klippart,
} Assistant Geologists.

In addition to those whose names are enumerated above, a number of persons were employed as local assistants, for whom also provision was made in the law, namely:

Rev. H. Hertzer,	Andrew Sherwood,
M. C. Read,	R. D. Irving,
Frederick Prime, Jr.,	W. A. Hooker,
W. P. Ballantine,	W. B. Potter,
G. K. Gilbert,	Henry Newton,

H. A. Whiting.

Of these Mr. Hertzer, who had been for many years a diligent student of Ohio geology, and had discovered the most interesting series of fossil remains yet found within our territory—was paid from the salary of the Chief Geologist, as a compensation to the State for any time devoted by him to other duties. Mr. Prime, a graduate of the School of Mines of Freiberg in Saxony, was engaged for three months, at $50 per month. Mr. Read, who had also had considerable geological experience, was paid $100, and Mr. Ballantine $50 per month, during the season when field work was practicable. Of the other members of the corps, Messrs. Gilbert and Sherwood were geologists who had devoted much time to practical geology in New York and Pennsylvania, and who, for the purpose of adding to their experience, volunteered their services for no other compensation than their traveling expenses. The five remaining names on the list are those of graduates of the School of Mines of Columbia College, who brought to our work a thorough preparation in chemistry, mineralogy and metallurgy, and who also gave their services during the summer, with no other compensation than their expenses.

The law providing for the Geological Survey requires a careful agricultural survey to be made, and as Mr. Klippart, one of the Assistant Geologists appointed by the Legislature, had for many years devoted himself to the study of agriculture, and since 1856 had filled the position of Secretary of the State Board of Agriculture, the agricultural department was committed to him.

The purely chemical work of the Survey, a most important department, was committed to Prof. T. G. Wormley, of Columbus, one of the best chemists in the country.

The law authorizing the Geological Survey provides that such survey should begin on the first of June, 1869, "or as soon thereafter as practicable." In accordance with this provision, the members of the Goelogical Corps entered upon their duties at this date.

The first duty required by law of the Geological Corps was the accurate determination of the Geological structure of Ohio. This was a necessary prerequisite to all the subsequent work of the Survey. During the many years that had passed since the former Board was disbanded, geological surveys had been maintained, with more or less thoroughness, in New York, Pennsylvania, Kentucky, Indiana, Illinois, Missouri, Arkansas, Kansas, Iowa, Wisconsin, Michigan and Canada, and the observations made by the geologists of those States in different and widely separated localities, had presented discrepancies that had given rise to long, earnest, and, sometimes, bitter discussions. Before the diverse conclusions of these various observers could be harmonized, and the succession and distribution of the rocks represented in our geology be fully made out, it was necessary that these views should be compared in Ohio; that observations made east, west, north and south should here be connected. Ohio thus, in some sort, formed the key-stone in the geological arch reaching from the Alleghanies to the Mississippi; and for many years geologists in our own country and abroad, had been looking forward with great interest to the time when the geological survey in Ohio should supply this key-stone, and render our whole geological system complete and symmetrical. It was also necessary that our work should be first of all blocked out in its generalities; that we should learn precisely what formations were represented in the State, their order of superposition, their mineral character and contents, their thickness and the geographical areas occupied by their outcrops.

To accomplish this work, our field was divided into four districts, consisting of the north-east, the south-east, the south-west and the north-west quarters of the State, all cornering at Columbus. The immediate supervision of the work in the north-eastern section was assumed by myself;

that of the south-eastern quarter by Prof. Andrews; of the south-western by Prof. Orton; of the north-western by Mr. Hertzer and Mr. Gilbert. To Prof. Andrews were assigned Messrs. Ballantine and Irving as assistants; to Prof. Orton, Messrs. Newton and Whiting. Messrs. Read, Sherwood, Hooker and Potter were occupied in the northern half of the State, and Mr. Prime devoted himself to the duty for which he was especially qualified—the investigation of our mines, and manufactures based upon mineral staples.

Fortunately for the success of our efforts in this portion of our duty, an excellent topographical map of Ohio had recently been made by my friend, Prof. Walling, and published by H. S. Stebbins, of New York. Of this map numerous copies obtained in the sheets were placed in the hands of the members of the corps. To economize time, and secure the benefit of a division of labor, the different formations were assigned to different observers. The younger members were made each familiar with a stratum or formation, and then, with map in hand, they followed it wherever it led, carefully tracing its line of outcrop. They were also instructed to make observations and take notes on all the subjects we were required to investigate, with the injunction to so thoroughly perform their work along each line of observation that it might never be necessary to go over the ground a second time. The scope of the observation made by our corps will be best comprehended from the following schedule of instructions, placed in the hands of all:

DIRECTIONS FOR OBSERVING AND COLLECTING.

1. *Topography.*—Note, a.—Altitudes of important points, by barometer, or by reference to railroad or canal levels.

b.—Topographical features and cause of ditto.

c.—Get railroad or canal profiles wherever possible.

2. *Soil.*—Note character (sand, clay, loam, muck, wet, dry, &c.), depth, origin, relations to underlying rock.

3. *Vegetation.*—Note nature of vegetation and its relation to soil and geological structure.

4. *Surface Geology.*—Note, a.—Superficial Materials (clay, sand, gravel, &c.), of local or foreign origin? stratified? thickness? fossils?

b.—Glacial Surface—planed? scratched? furrowed? direction of furrows.

c.—Terraces and Lake Ridges.—Composition, extent, altitude.

d.—Peat Bogs and Marl Beds; under former or present marshes. To be sought by boring. Fossils are elephant, mastodon, &c.

e.—Depth of rock—bottoms of valleys and stream beds. Often 100 to 200 feet below present streams.

5. *Geological Structure.*—Note lithological character, thickness, subdivisions, faults, dip, strike and fossils of each stratum. Trace geology on map. Take sections and sketches.

6. *Economic Geology.*—Note — Iron Ore — Coal — Clay—Peat—Marl—Manganese—Phosphate of Iron—Infusorial Earth—Glass Sand—Building Stones—Stone for flagging, paving, furnace hearths—Limestones—Hydraulic Limestones—Gypsum—Petroleum—(Wells, Springs, Sections of Wells)—Mineral Springs—Salt Springs, Licks, Wells—Gas Springs—Mineral Paint—Calcareous Tufa—Water Supply, Springs, Wells, (Sections of Wells)—Note quality, quantity and accessibility of all of the above economic minerals met with. If mined or manufactured, the quantity and quality of the mined or manufactured article.

7. *Indian Relics.*—Note mounds, earthworks, inscriptions—Excavate and survey—Collect bones, arrow-heads, axes, spears, pottery, &c.

8. *Manufactures* (of Mineral Staples).—Note, source, quality and cost of material—Quantity, quality and price of product—Construction of works—Statistics of 1868, 1869. Get suits of raw and manufactured materials.

9. *Mines.*—Note geographical position and accessibility—kind, quantity and quality of produce—plan of mines and works.

10. *Collecting Specimens*—Of rocks of each formation and important stratum—with and without fossils—collect ten sets 3x4x1 inch. Coal, iron ore, clay, &c., 3x4x1 inch. Fossils, as many good ones as possible.

Label or number each specimen in the field. Wrap in soft paper; pack in boxes, if possible, of not over two cubic feet capacity, flat specimens on edge. Fill the box. Tack on addressed card, with district, locality and number of box, and name of collector. Ship by express or freight, taking receipt.

The general results of the work of the Geological Corps during the last half of the year 1869, were embodied in a report of progress published in 1870 by order of the Legislature. This volume contains a report on the organization and progress of the survey; a sketch of the geological structure of the State, accompanied by a preliminary geological map, and a geological chart in which the formations contained in Ohio are brought into relation with the entire series of rocks comprising North America, and with the geological column of Europe; also a sketch of the Economic Geology of the State, including an enumeration of its deposits of useful minerals, with an outline of the plan to be pursued in studying their quality, quantity, distribution and manufacture; these by the Chief Geologist. The volume contains, in addition, a report on the geology of the south-eastern portion of the State by E. B. Andrews, and a report on the geology of Montgomery county by Edward Orton.

The most interesting and important portion of the report of 1869, is the exposition which it gives of the geological structure of the State, now for

the first time accurately determined. This had been designated in the law authorizing the survey, as a special subject of investigation, and a general geological reconnoisance was regarded as a necessary preliminary to all subsequent detailed work. Hence this occupied most of the time of the corps during the first season of field work, and resulted in settling all doubtful points respecting the relations of the geology of Ohio to that of States lying east and west of it, and in doubling the number of formations known to be represented in the State. Among the mooted questions to which reference has been made, that of the age of the Waverly claims special notice, as it had been discussed with much interest, and some bitterness, for many years. By a careful study of the fossils of this formation, and by tracing its continuation into other States, it was demonstrated to be of Lower Carboniferous age, and the equivalent of the "Vespertine group" of Rogers, in Pennsylvania; of the "Sub-carboniferous sandstones" of Owen, in Kentucky, and of the "Silicious member of the Lower Carboniferous group" of Safford, in Tennessee. Several other doubtful points in the geology of Ohio, of nearly equal importance, were cleared up by the corps in 1869, and the report of progress which embodied the fruits of their labors, was a popular and useful document, and one which served a good purpose in preparing our people to appreciate, and intelligently use, the subsequent and more detailed publications of the corps.

In the Spring of 1870 the Legislature made a more liberal appropriation (of 18,000 dollars) for the support of the survey, and it was prosecuted during the year with more vigor than before. No change was made in the *personnel* of the corps, except by the withdrawal from the group of Local Assistants of Messrs. Prime, Sherwood, Irving, Hooker and Whiting, and the appointment of Mr. Hill as local assistant to Prof. Orton.

The results of the work of the corps during 1870 are embodied in a report on the "Progress of the Geological Survey in 1870," published in 1871, and forming a volume of 568 pages 8vo. This volume includes a report of the "Progress of the Geological Survey," and a "Sketch of the structure of the Lower Coal Measures of North-eastern Ohio," by the Chief Geologist; also a "Report of labors in the second geological district, during the year 1870," by E. B. Andrews; a report on "The Geology of Highland County," with a "Description of the Cliff Limestone of Highland and Adams Counties," by Edward Orton; a "Report on the Agriculture of the Maumee Valley," by J. H. Klippart; a "Report of the Chemical Department," by T. G. Wormley; "Sketches of the Geology of Geauga and Holmes Counties," by M. C. Read; "Sketches of the Geology of Williams, Fulton and Lucas Counties," by G. K. Gilbert; "A sketch of the present state of the manufacture of iron in Great Britain,"

by Wm. B. Potter, and "A sketch of the present state of the Steel Industry," by Henry Newton.

Though less general in its scope, and less popular than the preceding, this volume contains a mass of facts, which attest the industry of the corps, and such as could not but be useful to the people of the State. The reports on iron and steel of Messrs. Potter and Newton, presenting as they do, graphic and accurate pictures of the present condition of these great industries, in the countries where the arts of iron and steel making have been carried to the greatest perfection, have been regarded by our iron-masters as of special interest and value. It should also be said, that these reports embody the results of personal observations made by their authors in all the centers of metallurgic and mining industry of the old world; and that for such inspection they were prepared by as thorough training in metallurgy as could be obtained in this country.

In the report of progress for 1870, the Chief Geologist gives a schedule of the volumes that are to form the Final Report, which by the organic law of the survey, he is required to make. This report is planned to consist of four volumes, 8vo., namely: the present as Volume I, devoted to Geology and Palaeontology; Volume II, treating of the same subjects; Volume III, on Economic Geology; Volume IV, on Agriculture, Botany and Zoology. Of the second report of progress fourteen thousand five hundred copies were published.

During the session of 1871 the Legislature made a still larger appropriation than before, for the continuation of the survey, namely, 21,000 dollars, and the work was pushed with increased vigor. No marked changes took place in the membership of the corps, the Chief Geologist and Assistant Geologists continuing on duty, Prof. T. G. Wormley still acting as Chemist, and F. B. Meek as palaeontologist. Among the local assistants some changes occurred; Mr. W. G. Ballantine and Mr. G. K. Gilbert having left the corps; Prof. J. T. Hodge,* Prof. J. J. Stevenson,

* Prof. Hodge was one of our most experienced and esteemed Geologists. He was one of the assistants on the survey of Pennsylvania in its first organization, was for one year at the head of the Cooper Union in New York, for several years employed in the editorial corps of Appleton's Cyclopedia, for which he wrote a large part of the scientific articles, and was subsequently occupied in various public and private geological surveys, which carried him to nearly all parts of our country. He had made a survey and report on Coshocton County, and was engaged on a reconnoissance in Tuscarawas, Harrison and Jefferson Counties, when to escape his annual scourge of hay-asthma, about the middle of August he went to Lake Superior. On his return he chanced to be a passenger on the ill-fated Coburn, which foundered in Lake Huron, with the loss of all on board. Prof. Hodge as a geologist held deservedly high rank, he was also a man of general cultivation and of peculiarly refined and lovely character.

Prof. John Hussey and Messrs. N. H. Winchell, Ogden Haight, H. M. Smith, Robert Warder, S. A. Goldsmith, L. Lilienthal and A. W. Wheat, were added to it, for a longer or shorter term of service; several of them as unpaid volunteers. Four parties were kept constantly in the field—for the most part engaged in making county surveys,—with the result that at the close of the season about three-fourths of the area of the state had been examined in detail. A brief sketch of the progress of the geological survey during 1871 was submitted by the Chief Geologist, and published by the Legislature of 1872. This is a pamphlet of eight pages, and consists of a simple business report of the progress and prospects of the work. It was made thus brief, in order that it might be published immediately and form the basis of action by the Legislature to which it was presented. The preceding annual reports had, in a degree, failed to meet the demand of the Legislature for fresh information in regard to the Geological Survey, inasmuch as each report of progress had been accompanied by voluminous, illustrated geological reports, by which the publication had been delayed for many months. The publication, too, of so much matter in the form of annual reports had resulted in the suppression or postponement of all the materials prepared for the final report; and it was evident the final report would never see the light if the system of voluminous annual reports were maintained. In the progress of the survey a large amount of interesting and valuable material had accumulated which the interests and dignity of the State of Ohio required should be put on record in a permanent and creditable form. The annual reports, useful as they were, necessarily gave an imperfect presentation of the subjects of which they treat. Being published in a somewhat cheap style and without plates, even if multiplied to any number, they would not fairly represent the results obtained by the survey, nor be in keeping with the large sums expended on it. Nor would such a series of volumes bear comparison with the geological reports published by our sister states. Hence the report of progress for 1871 was given the subordinate and practical character contemplated by the framers of the law authorizing the geological survey, and required by the wants of the Legislature; while of the elaborated material which had accumulated to this date sufficient was selected to form one volume of the final report, and this was presented to the Legislature for publication. It was the judgment of the Chief Geologist that 5,000 copies of this volume would supply the real want it would meet, and that if a larger number than this were published they should be placed on sale at the cost of publication. These views were, however, not shared by the members of the Legislature, as an edition of 20,000 copies was ordered printed, and a very liberal appropriation made for the engraving of the

illustrations which accompanied the manuscript. If it shall seem to some that the expenditure for this volume is an extravagance, it is but just to the members of the geological corps to say that so large an expenditure was not sought by them, and that the responsibility rests entirely with the Legislature. There are some reasons, also, why the sum appropriated for the publication of this volume should not be considered excessive. When we consider the great area and population, and the immense mineral wealth of our State, and recognize the craving for information in regard to our geology, indicated by the demand which has promptly exhausted the large editions of the annual reports, we shall perhaps not regard the edition authorized of the present volume,—of much more permanent and general interest—as too large. As a matter of policy, however, the matter has a different aspect, and if it should happen that another Legislature failed to possess, in an equal degree, the enlightenment which has prompted so liberal an appropriation for the dissemination of scientific truth, and considerations of economy should put a stop to the publications of the results of the survey, it will be a matter of just regret that the large expenditure on this volume should prevent the appearance of others and the work be left incomplete.

Before this sketch of the origin and progress of the survey is brought to an end, some acknowledgment should be made of the aid rendered by individuals and corporations to the Geological Corps in the prosecution of their work. In almost every county which has been examined, some intelligent and public-spirited citizens have been found, who, from their knowledge of persons and places, and, in some instances, of general or local geology, have been able to afford information that has been of the greatest value. Not unfrequently it has also happened that such persons have hospitably entertained the members of the corps, have accompanied them in their visits to localities of interest, or have placed horses and carriages at their service. The list of co-laborers and volunteer assistants who have thus contributed to the success of the survey is too large for repetition in this general summary, but their names will be recorded, and the value of their services acknowledged, in the detailed reports of the counties in which they reside. I can here only refer to a few, to whom we are under special obligations for favors of unusual value, and such as will not be fully acknowledged elsewhere. In this list I should enumerate Mr. George A. Hyde of Cleveland, Mr. George C. Huntington of Kelley's Island, Dr. I. B. Trembley of Toledo, Dr. G. O. Hildreth of Marietta, Prof. S. N. Sanford of Cleveland, Mr. Joseph B. Doyle of Steubenville, Mr. D. B. Cotton of Portsmouth, George W. Harper of Cincinnati, and Mr. M. G. Williams of Urbana, for tabulated reports on climatology, embodying the results of many years of careful observations. To Messrs.

C. B. Dyer, S. A. Miller, and U. P. James, of Cincinnati, who have generously placed at our disposal their splendid collections of fossils, the fruits of years of industry, we owe special acknowledgments. The specimens of which they have given us the use include many new and interesting species which have supplied the most interesting material illustrated in Mr. Meek's palaeontological report. Of those who have rendered valuable assistance in the prosecution of the field work, I take pleasure in recording the names of Mr. C. H. Andrews of Youngstown, Mr. John Campbell of Ironton, and Col. W. H. Trimble of Hillsborough. The officers of several railroad companies have also afforded us favors which have materially diminished our expenditures, and have greatly facilitated our work. Among these, our grateful acknowledgments are due to J. H. Devereux, Esq., General Manager of the Lake Shore R. R.; to Messrs. J. N. McCullough and R. T. Smith, President and Vice President of the C. & P. R. R.; Messrs. L. M. Hubby and Oscar Townsend, President and Vice President of the C., C. & C. R. R.; and Judge R. C. Hurd, President of the C., Mt. V. & D. R. R. We are indebted to the officers of other railroads for many favors, but the promptness and courtesy with which free transportation has been accorded to all of our members by the gentlemen enumerated, fully deserve the record now made.

In general, it may be said, that the people of the State have manifested the deepest interest in the prosecution of our work, and have cordially co-operated with us by all the means at their command. The proprietors of mines, furnaces and other establishments using our mineral staples, have, with one single exception, given us cordial welcome and free access to their premises; have fully exposed their machinery and processes to our inspection, and have afforded us much other substantial assistance in many ways. We should be culpably ungrateful, in face of the hearty co-operation we have experienced, did we not earnestly endeavor, by our efforts in the development of our mineral resources, to repay the many obligations which we have incurred.

CHAPTER II.

PHYSICAL GEOGRAPHY.

CLIMATE.

The climate of Ohio, like that of most of North America is one of extremes. This is dependent in a large degree upon the position and character of the principal topographical features of the continent. Our territory, extending some three thousand miles from east to west, and about half that distance from north to south, is traversed by four great mountain ranges, all of which have an imperfectly north and south direction, and beyond the limits of our own possessions we look in vain for any great feature discordant with the system of topography produced by these lines of elevation. As a consequence the surface of our country forms a series of valleys, or, more properly, plains, separated by these mountain ranges, and opening without barriers to the north and south. These plains have, therefore, no defense against the arctic winds of winter that sweep down from the snow-covered North, nor from the tropical heat which is borne on the summer winds that come to us from the South. The result is a seasonal variation of temperature scarcely paralleled on any other great portion of the earth's surface; amounting to over a hundred degrees throughout the greater part of the inhabited portion of our territory. A climate exhibiting such extremes must produce a marked effect upon the health and habits of the people who live under it, but here as well as elsewhere in nature, a system of compensation so nearly balances the good and the evil that it is not easy to say whether, on the whole we are gainers or losers in the possession of a climate so peculiar. If our summer is enervating, our winter is correspondingly bracing. And if the vegetation of our fields is parched by the summer's heat, and made gray and lifeless under the influence of the winter's frost, still, in virtue of our tropical summer we are able to cultivate over an immense area, the two most useful agricultural staples known to man, viz.: *corn* and *cotton*. Both these are annual plants, and now reach maturity at points much further north than would be possible if our summer and

winter temperature were more evenly balanced. These staples supply at once the first necessities of humanity, food and clothing; and produced as they are in such perfection and abundance in our country, they make an annual contribution to our wealth which cannot be reckoned at less than five hundred millions of dollars.

On the other hand, the north and south topographical features to which I have referred interpose almost impassable barriers to atmospheric movements in an east and west direction. On the western side of our continent the prevailing winds are from the west, and come to the land bearing the temperature of the equable Pacific; hence the climate is there greatly modified—we may almost say is created by them. These warm winds reach the coast laden with moisture. Here they cross a cold arctic current, sweeping an "iron-bound" shore. Chilled by its influence their vapor is condensed producing mist and rain which are driven upon the slopes of the Coast mountains. A very copious precipitation of moisture is thus caused; and the annual rain-fall of the north-western coast is greater than that of any other portion of our possessions. Passing the Coast ranges, the ocean winds enter the great longitudinal trough of the Californian valley where the summer temperature rises daily for weeks together to above a hundred degrees. Here their capacity for the absorption of moisture is increased and they become drying winds. Reaching the slopes of the Sierra Nevada, which forms a high and almost unbroken mountain wall, they are cooled and again robbed of some portion of the vapor which they bear, thus creating another, though less strongly marked north and south rainy belt. After passing the Sierra Nevada the westerly winds sweep over the plateau of the Great Basin, where in some districts almost no precipitation takes place, and where as a consequence we find the only true deserts known upon our continent.

Still further east the Rocky Mountains form another condenser, and their summits are enveloped in clouds and bathed in showers derived from the upper currents of the Pacific winds. In the broadest portion of this mountain belt the Columbia, the Missouri, the Arkansan Red River, the Rio Grande and the Colorado take their rise. By this great condenser the rain-producing power of the westerly winds is nearly exhausted; and immediately east of it and under its lee we have the remarkable physical feature of the "plains," a treeless, grass-covered surface, forming a belt five hundred miles in width skirting the bases of the Rocky Mountains from Texas far into the Canadian territory.

Borne on the wings of this great system of westerly winds we have now been floated from the Pacific over all our great mountain belts, and have been brought into what we have styled the Mississippi valley,

because it forms the hydrographic basin of that stream, but which is in fact a great plain stretching from the Rocky Mountains to the Alleghanies, and from the Gulf of Mexico to the Canadian highlands beyond the lakes. In this region the influence of the westerly winds has nearly ceased, and if we were dependent upon the vivifying power which they exert, this great area would be a more hopeless desert than any that lies west of it. Here, however, we come within the scope of a different system of climatic influences; and such as are sufficient to make this plain perhaps the most congenial abode of humanity of all the great areas of the earth's surface. The cause which has given fertility to all parts of the Mississippi valley is mainly the sweep of the Atlantic system of winds, which, leaving the Gulf of Mexico with a north-easterly direction, flow in a broad curving stream over most of the area lying between the Gulf and Lake Superior, and between the Rocky Mountains and the Atlantic. As storms are local phenomena—eddies, whirlpools, etc.—in this current, the tracks of these storms form parallel curves, cutting more or less of our territory, according to their position east and west in the broad belt of rain-bearing wind. The moist winds which sweep over the Gulf of Mexico come to the borders of our southern states with their full burden of vivifying freight; thence in their north and north-easterly course meeting with the cold, return winds, which blow from the north-west, their moisture is precipitated and distributed with remarkable regularity over all the territory which they reach. The annual rain-fall at different points in the area traversed by these currents of winds, is measured with considerable accuracy by their positions on the lines of these curves and on their radii, the rain-fall diminishing from Mobile to Denver, and, by the progressive exhaustion of transported moisture, from New Orleans to Niagara Falls. In the region of the lakes the annual rain-fall is increased and the area of forest-growth and successful agriculture is extended by the evaporation from these great water surfaces. The flood which flows through the St. Lawrence in certain parts of its course being checked and spread, evaporated and precipitated again and again, serves to fertilize all the shores of the lake system. In this connection I may say that it is impossible to over-estimate the importance to us of the position of the Gulf of Mexico with reference to our territory. By this deep excavation of our continental shores, a great evaporating surface of warm water is spread all along our southern border, and it requires no stretch of the imagination to comprehend that the filling up of the Gulf would at once condemn to sterility a large part of the Mississippi valley. And this is but one of the many methods or measures by which this valley is fitted for human habitation.

In following the track of the rain-bearing winds which pass over our continent, we have seen that owing to the interposition of the topographical barriers to which I have referred, the annual rain-fall has been made to vary greatly in different districts, and we find this variation ranging from eighty inches on our north-west coast to two inches in portions of the Great Basin. An accurate index of the amount of annual precipitation may be found in the character of the vegetation which occupies the surface. In the areas we have considered, the belts best supplied with moisture are covered with forest growth. Those having the minimum rain-fall are bare and barren deserts. The great areas of an intermediate character, where the annual rain-fall is twenty inches or less, are covered with grass, and these are the prairie regions, and this the cause of the distribution which we observe of herbaceous and arborescent vegetation. Lying as Ohio does, beneath the parallel circles of the Gulf winds, and bordering on one of our great Lakes, the annual rain-fall in different parts of our state is dependent directly upon the causes that I have ennumerated; and we find in accordance with the plan that has been sketched, that the rain-fall is greatest at the southern margin and least at the northern: the range being from forty-four inches about Cincinnati and along the Ohio, to thirty-two inches on the Lake shore.

The belts of mean annual temperature that cross the surface of Ohio lie between the isothermal lines that curve over our continent, in obedience to the influence of its characteristic topographical features; being carried far to the south by our mountain ranges, and curving more gently to the north over our great areas of depression. On either side of our continent deflections of the isothermals are produced by the influence of the Gulf stream on the one hand, and of the warm Pacific winds on the other.

The annual mean temperature of the southern part of our territory in the valley of the Ohio is at Cincinnati fifty-four degrees, and at Marietta fifty-two degrees Fahrenheit. The average annual temperature of our northern tier of counties is about fifty degrees Fahrenheit, and this follows with considerable accuracy the outline of the lake shore. On the highlands back from the lake the annual mean falls to forty-nine, and even locally to forty-eight degrees; the lake exerting an equalizing influence which is felt both in summer and winter.

It is a well-known fact that land surfaces produce extremes of climate—the winter being cold, the summer hot over them—while in the central portions of large bodies of water the temperature varies to a much less degree. Even lakes of limited size are great equalizers of the cli-

mate of their shores. The surface of the interior of our great lakes is never frozen, hence, the wind which sweeps over those surfaces is in winter warmed by the water, and, in turn, warms the shore upon which it blows. The influence of a large lake lying in the track of prevailing winds is most notably seen in the case of Lake Michigan. The general direction of the winds being there westerly, they come to the shore of the lake, hot in summer and cold in winter, exhibiting the extreme character of the climate of the great continental surface which they sweep. They arrive on the eastern shore of Lake Michigan, however, with the temperature equalized by the great body of water over which they have passed. As a consequence the western portion of the lower peninsula of Michigan is remarkable for the equable character of its climate. All points along this coast are warmer in winter and cooler in summer than corresponding points on the opposite shore.

In a less degree Lake Erie exerts a similar influence over the climate of its southern shore. It is not so broad nor deep as Lake Michigan, and lies less directly across the track of westerly winds; but as most of our winter winds come from the north-west, before reaching the counties of the Western Reserve, they pass over a considerable portion of the surface of Lake Erie, and are sensibly warmed by it. This is proven by the differences which the extremes of winter temperature present immediately on the lake shore and at points some miles back in the interior. As a general rule it will be found that the mercury falls at least ten degrees lower, thirty or forty miles back from the lake than upon its margin. In summer the difference is not so strongly marked by the thermometer, but the influence of the lake is even more apparent in its effect upon the comfort of the inhabitants of its shores, for during the summer months a day breeze blows from the water to the land with as much regularity as at the seaside. Usually the thermometer marks a difference of at least five degrees between the extreme summer temperature of the lake shore, and the interior, although the high lands which form the rim of the lake basin are seven hundred feet higher than the lake itself.

In appendix A of this volume will be found the tabulated records of observations on rain-fall and temperature made at ten stations in Ohio during a period of years. Abstracts from these tables, giving the monthly and annual mean of rain-fall and temperature will be found on the following pages:

Monthly and annual quantity of water from rain and snow reduced to water, in inches and hundredths of an inch, for a period of years in Northern, Middle and Southern Ohio.

Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean of the years observed.	Extent of series of years.
Marietta	3.94	2.80	3.82	4.00	3.75	3.43	4.85	3.71	3.62	2.88	2.76	2.95	42.65	12
Portsmouth	2.84	2.90	3.98	3.69	3.98	3.00	3.86	3.59	3.70	2.72	3.30	3.09	41.65	11
Cincinnati.........	3.38	3.41	3.84	3.45	4.64	5.22	4.47	4.51	3.10	3.34	3.53	4.54	47.43	18
Steubenville	2.94	2.75	3.38	3.53	3.85	4.01	3.89	3.97	3.48	3.18	3.16	3.34	41.48	37
Urbana	2.62	2.42	3.46	3.56	3.92	4.42	3.54	3.61	3.69	2.38	3.34	3.50	40.45	20
Hudson	2.67	2.16	2.43	3.36	3.61	3.13	3.68	3.21	4.20	2.44	3.35	2.65	36.23	10
Cleveland	2.20	1.98	2.92	2.95	3.50	3.49	2.85	2.90	4.25	2.66	3.34	2.55	35.59	10
Kelley's Island...	1.63	1.74	2.63	3.10	3.30	3.48	3.53	2.32	3.44	2.29	2.59	2.26	26.92	10
Toledo	1.7986	1.2642	3.8502	3.6249	4.3877	4.4583	3.5594	2.9844	4.1186	2.3957	3.1138	2.3629	38.9087	9
Granville...........	2.47	3.65	3.35	3.64	3.53	5.59	4.82	6.82	2.70	3.03	4.11	5.21	48.62	7

Monthly and annual mean temperature for a period of years, at ten stations in Northern, Middle and Southern Ohio.

Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the years observ-ed.	Extent of se-ries of years.
Marietta	30°.57	34°.05	40°.67	51°.99	60°.03	68°.88	72°.99	71°.70	64°.83	52°.80	41°.14	32°.70	51°.86	12
Portsmouth	34.07	37.78	43.78	55.16	64.59	72.46	76.67	74.33	68.07	53.30	44.64	36.11	55.08	11
Cincinnati.........	31.20	35.54	42.65	54.07	64.24	73.74	78.61	75.76	67.68	55.50	42.88	34.98	54.67	16
Steubenville	31.60	32.60	39.30	55.0	64.1	73.60	75.6	73.8	67.6	53.4	41.4	32.6	54.	6
Urbana	26.47	30.26	38.37	50.40	61.52	70.22	74.31	71.66	64.79	51.69	39.78	29.86	50.70	20
Hudson	27.16	30.48	34.06	46.78	58.66	68.95	72.38	71.16	63.66	50.23	40.44	30.36	49.53	10
Cleveland	27.36	30.14	35.69	47.50	57.33	68.00	72.57	70.63	63.67	51.77	41.12	31.47	49.77	10
Kelley's Island...	26.45	28.94	34.11	45.73	57.24	68.92	74.05	72.61	65.67	52.87	42.24	30.23	49.92	10
Toledo	26.455	30.517	35.349	46.995	58.86	68.505	73.469	70.778	62.927	50.007	40.218	30.242	49.527	10
Granville..........	27.58	32.87	38.06	50.99	60.67	70.34	75.02	69.96	64.93	51.80	42.55	31.72	51.38	7

Before leaving the subject of our climate I ought, perhaps, to refer to a question frequently asked. How far has our climate been modified by the removal—so for as it has been removed—of the dense forest which once covered nearly all parts of the surface of our state? This subject will doubtlessly be fully discussed in the agricultural portion of our report, yet as it bears upon the flow of our rivers, now the most potent of all agencies in effecting changes of the surface, an allusion to it seems to be required here. The opinion very generally prevails that the removal of the forest materially diminishes the rain-fall and the volume of the streams, and hence is productive of droughts. That the humidity of the climate is diminished by the removal of forests, can hardly be doubted, but that the annual rain-fall is materially lessened by this cause is by no means proved. A more complete series of meteorological observations, and those continued over a longer interval than any yet made in our country, would be necessary before it could be demonstrated that the cutting off of our forest had been entirely without influence upon the annual rain-fall. Such observations as have been made however—at Marietta, for example, which cover an interval of fifty years—seem to prove that if any change in the rain-fall is due to this cause, it is very slight. I learn from Prof. Henry that the extensive system of observations of which the records have been collected and tabulated by the Smithsonian Institution, has failed to indicate any appreciable effect produced on the annual precipitation by the removal of forests. The fact seems to be that a dense forest growth is a great *equalizer* both of temperature and the flow of surface water. While the forest is unbroken it acts as a blanket, covering the soil, protecting it from the winds, both drying and chilling. It serves also as a great sponge, receiving and retaining moisture and allowing its gradual escape. When the forest is removed, however, and the soil cultivated, the surface smoothed, the drainage facilitated, as it is in a thousand ways, and the sun and winds admitted, the effect cannot but be marked, even though the annual rain-fall be not materially changed. The most noticeable result is seen in the greatly increased variation of volume in the draining streams. When heavy rains come or snows are melted, the water flows rapidly and freely away, floods or freshets are produced in our rivers by which the surplus water is carried off and unprecedented disasters are occasioned. In the drier season a corresponding deficiency is produced, the water in our streams sinks proportionately below its former level, and they become more uncertain as channels of navigation and as sources of motive power. Districts before well watered are made to suffer from drought, so that the practical evils caused by the removal of the forest, are no less real and

calamitous than though the annual rain-fall had been materially reduced.

The wanton waste of timber which has marked the subjugation, as it is called, of our forest-covered country, must painfully impress the economist who sees in the primeval forest one of the most valuable crops the soil is capable of producing. It offers a theme which may well engage the attention of the agriculturist and the statistician, but which can hardly with propriety be pursued further here.

The climatic result which will be attained, should the destruction of our forests continue, is well shown in the present condition of the prairie country at the far west. There, over large areas, the annual rain-fall is sufficient to supply all the wants of the agriculturist, if it could be properly husbanded. As it is, however, the heavy rains, which are not wanting there, flood the country for a moment, but the great volume of water passes away almost as rapidly as it comes. The smooth, inclined surfaces shed the rain like roofs. For a brief interval the valleys are filled with floods, and every tinkling rill becomes a resistless torrent. I have known, in Kansas, a stream usually insignificant, rise forty feet in a single night, and subside almost as rapidly. Within a few hours after copious rains, their effects have entirely passed, and the surface, exposed to the full force of the sweeping winds and unprotected from the sun, suffers all the bad consequences of drought.

Some facts have recently come to my knowledge, which indicate changes in our rain-fall or in the volume of some of our rivers, for which it is not easy with our present knowledge to account. It is well known, for example, that all our streams which afford water-power that has been utilized for the propulsion of machinery, have become much less constant in their flow than formerly. In summer and in dry seasons, water in them, falls lower than it was ever known to do by the earlier inhabitants. So, too, the Ohio which afforded such a magnificent and reliable channel of navigation to the early settlers of the State, of late years has lost its prestige, and has exhibited such fluctuations of level as seriously to embarrass all the commerce upon its waters. During the last two seasons, which have been unusually dry, the water in the Ohio and its tributaries sank lower than was ever known before. At Smith's Ferry—where the Pennsylvania line crosses the Ohio river, a ledge of rock was by the continual drought laid bare in the bottom of the river, which had never been so fully exposed to the observation of the present inhabitants of this region. On this ledge, a surface from fifty to one hundred feet wide and several hundred yards long, was found covered with inscriptions, such as are usually ascribed to a race which densely populated this country anterior to the advent of the nomadic Indians. The existence of

these ancient hieroglyphics, now almost constantly buried beneath the waters of the Ohio, seems to prove that these rocks were once longer and more fully exposed than they now are, and that the volume of water in the Ohio, was then less than now. The facts I have stated, associated as they are with others of similar import which have come to my knowledge, indicate a period when our climate was drier than now, or one when from natural or artificial causes, the oscillations of level in the Ohio were greater than they have been during the last fifty years. It is among the possibilities that we have here the record of the effect produced upon the climate of this portion of our country, through its occupation during hundreds, perhaps thousands, of years by a dense, agricultural population. Much more proof would be required before we could accept such a conclusion as established, but the facts I have cited seemed to me interesting, and if confirmed by others of like character, may prove very instructive. They will, at least, stimulate investigation.

SOIL AND AGRICULTURE.

The nature of the soil, the agricultural capabilities and the vegetation of our State are matters which more immediately concern the agriculturist and will receive attention on the part of the Assistant Geologist who has charge of the Agricultural Survey. A few words, however, in allusion to these subjects seem to be required in a chapter devoted to physical geography, of which they form an integral and essential part.

The soil over much more than half of the state is of foreign origin, that is, has not been derived from the decomposition of the underlying rocks, but has been transported, by Drift agencies, frequently from a great distance. Over the northern part of the state the most conspicuous element in the Drift deposits is clay. As a consequence we have the monotonous surface already described, formed by a tenacious, clayey soil which has given character to the original forest and to the system of agriculture which has succeeded that. In this district we find regions that, in ordinary seasons, are somewhat wet, the primeval forest composed mainly of elm, bass wood, ash and hickory, and the agriculture which has been most successful, the cultivation of grasses, the raising of stock and the manufacture of butter and cheese. On the Western Reserve, the underlying rocks are frequently highly arenaceous—such as the Carboniferous conglomerate and the Berea sandstone—yet, this is the dairy of the West, for over nearly all parts of the surface a sheet of Drift clay has been spread, of such continuity and thickness as completely to modify the character, both of the vegetation and the agriculture.

Along the southern range of counties on the Reserve, in Stark, Wayne and Richland, and so on toward the south and west, the Drift deposits are more or less composed of gravel and sand. As a consequence we here have a lighter, more loamy soil, a prevailing growth of oak in the forests and the successful cultivation of cereals.

In the coal area the lands are generally high, the Drift deposits limited in thickness and extent, and, consequently, the underlying rocks have, more than elsewhere, affected the character of the soil. These rocks are sandstones, shales, limestones, fire-clays and coal, materials which, according to their relative preponderance, have given marked local diversity to the soil. Some of the ridges, formed mostly of sandstones, are covered with a light and porous soil having comparatively little agricultural value, and while in the state of nature, crowned with a dense growth of chestnut and wild grape. Others of the hills of this region are composed of shale which has produced a clay often barren and washing badly. More frequently, however, sheets of limestone which fertilize, and fire-clay which give rise to springs irrigating the hillsides, have made these highly inclined and perfectly drained surfaces much more fertile than would at first sight seem possible. Hence the traveler is constantly surprised to see in this region fine crops of corn growing on the summits of the hills. In this section of the state there is, comparatively, little level ground, and the view obtained from every eminence presents an endless series of hills of which the graceful outlines and cultivated surfaces present a pleasing but somewhat monotonous picture.

In the valleys of the Muskingum, Scioto and Miami, the soil is deep-black alluvium, which yields, year after year, abundant crops of Indian corn, the great agricultural staple of these districts.

On the waters drained by the Miami the underlying rocks are calcareous and the Drift gravels are usually largely composed of limestone. From both these sources fertilizing elements are imparted to the soil, and we have, as a consequence, one of the richest, as well as most beautiful sections of the state, an extension, in fact, of the famous "Blue grass" region of Kentucky.

THE ORIGIN OF PRAIRIES.

In the north-western part of our area are some prairies of considerable extent. The cause of the relative prevalence of arborescent and herbaceous vegetation in that district is to be found in local peculiarities of the soil and surface. Usually these prairies are remarkably level and are underlaid by a soil of unusual fineness scarcely permeable to atmospheric water. As a consequence they are alternately too wet and too dry for the growth of trees except where beds of gravel rock, or a more porous

soil permit the passage of the roots to a constant source of supply of moisture, as well as drain off the surplus during the wet season.

Much has been written about the causes of prairies, but I cannot better express my own judgment on this question than by quoting a paragraph from "A Catalogue of the Plants of Ohio," published by myself in 1860, just when I had returned from nearly five years journeying in those parts of our country where prairies abound. That paragraph reads as follows :

"The great controlling influence which has operated to exclude trees from so large a portion of our territory west of the Mississippi is unquestionably a deficiency of precipitated moisture. To this cause are due the prairies of Oregon, California, New Mexico, Utah, Nebraska, Kansas, Arkansas and Texas. Throughout this great area we find every variety of surface, and soil of every shade of physical structure or chemical composition—unless in exceptional circumstances where it receives an unusual supply of moisture—if not utterly sterile, covered with a coating of grass. The theories which have been proposed for the origin of prairies, *viz:* that of Prof. Whitney, that they are due to a peculiar fineness of soil, or that of Mr. Lesquereux that they are the beds of ancient lakes, that of Mr. Desor that they are the lower and level reaches of sea bottom, or, finally, that which attributed them to annual fires, are alike inapplicable.

"The prairies bordering on and east of the Mississippi may be and doubtlessly are, partly or locally due to one or more of the conditions suggested in the above theories, but even here the great controlling influence has been the supply of water. The structure of the soil of the prairies coincides with the extremes of want and supply of rain characteristic of the climate, and has made them now too wet and now too dry for the healthy growth of trees. A sandy, gravelly, or rocky soil and subsoil more thoroughly saturated with moisture and more deeply penetrated by the roots of forest trees, affords them a constant supply of the fluid which, to them, is vital. This, as it seems to me, is the reason why the knolls and ridges composed of coarser materials are covered with trees while the lower levels, with finer soil, are prairies."

Since the publication of the pamphlet which contains the above paragraph, much has been written on the origin of prairies, and some which will serve only to perpetuate and even increase the diversity of opinion which before existed in regard to this subject. Prof. Dana has written clearly and wisely, as he always does, in an article upon this theme published in the American Journal of Science. Col. J. W. Foster has touched upon it in his "Mississippi Valley," and there takes the view here advocated, showing by reference to the grass-covered plains that occupy the interiors of all the great continents, that our prairie region is no anomaly, but one of many examples, of the effect produced upon vegetation by a deficiency of moisture in level areas remote from great water surfaces. Supporting a different theory proposed by him some years since, Mr. Lesquereux has amplified this in a chapter (VII.) of

vol. I. of the Geological Survey of Illinois, published in 1866. In this chapter, as in his former papers, Mr. Lesquereux advocates the view that prairies are old lake beds, first occupied by aquatic plants, then as better drained or filled, covered with grasses which hold their ground and exclude trees by simple and complete occupation. He sustains this theory by citing the transformation of shallow bays into grassy marshes, such as are common enough along our lake margin. Sandusky bay is referred to as a typical example of the gradual formation of a prairie by this process. A sufficient refutation of the theory of Mr. Lesquereux as a general explanation of the origin of prairies, will be found in the fact, that west of the Mississippi, in the region of prairies *par excellence*, over immense areas, every variety of soil and all kinds of topographical features are covered with grass and form parts of the prairies. On the borders of the prairie region, belts of timber occupy the river valleys and stretch far out into the plains, fringing the margins of the water courses, because there, and there only, can they find the supply of water which is to them a necessity. Between the valleys, however, the divides, low and level, or high, rolling, or broken, are covered with a sheet of grass, and this in a belt five hundred miles wide, reaching from Mexico far into the British territory. The eastern border of this belt lies but a few hundred feet above the level of the sea, its western margin five thousand to seven thousand feet above that level; reaching up, indeed, on the flanks of the Rocky mountains, to a point where the altitude of these mountain masses makes them condensers that gather a supply of moisture which covers them with a forest growth.

That the prairies of Illinois, Indiana and Ohio have been, geologically speaking, recently covered with water and formed the bottom of one great, and subsequently of many smaller lakes, is unquestionably true, but this is equally true of the forest area which divides the surface with the prairies. The fact of the transformation of lakes or bays into prairies can not be denied, as many examples of such transition may be easily found, but the theory that grass follows the water as a necessity and holds the territory only by right of possession, is a *non sequitur*. The truth is that where areas of quiet water have been transformed into land, it often happens that the surface is formed by a peculiarly fine soil, and this soil is permanently occupied by grass; first, because some of the grasses are more aquatic than trees, and second, the species which succeed these will grow and flourish on a fine impervious soil which the roots of trees will not penetrate, since, when buried in it, they are all neither watered nor ærated, as they must be to sustain a healthful, arborescent growth. Prof. Whitney, in his contribution to the report of the geology of Iowa,

connects the firmness of the soil of the prairies which he studied, with the absence of trees; but fails to perceive that the phenomena hinge upon the hygroscopic character of such soils. Since that time he has traversed the prairies of the far west, and has seen in the Sacramento valley all kinds of soils—fine, coarse, gravelly, sandy, stony—where remote from the river, covered with an herbaceous vegetation, while the immediate river banks are occupied by belts of forest, composed of oaks of more magnificent growth than any to be found in the valley of the Mississippi. He has there learned that *water* in abundance and yet not in redundance is the vital element in tree growth.

Prof. Alexander Winchell has suggested yet another theory to account for the origin of prairies. That is, that the vegetation of the prairies is preglacial. That when the ice and water of the Drift period were withdrawn, the surface of the Drift deposits was covered with grasses which sprang from seeds that had retained their vitality since the remote period, when the arctic winter crept down from the far north and changed all our fruitful, blooming country into a waste of snow and ice. Upon this theory the testimony of botanists may be taken to advantage, in order to ascertain how long the seeds of plants can retain their vitality. The best geologists are agreed that the maximum of cold which produced the glaciers of the ice period, must have occurred not less than 200,000 years ago, the last period of great eccentricity in the earth's orbit. If this interval of time is not greatly overestimated, there are probably few botanists who would admit the possibility that the germs of plants could maintain their vitality long enough to permit the acceptance of this theory.

In regard to the origin of prairies, as with many other much discussed questions, a large part of the diversity of opinion which exists is due to the limited observation of many of those who have written upon it, and it is probable that if all those who have taken part in the discussion, could themselves traverse the great grass-covered plains of the West and could study on the spot the phenomena which they present, there would be but little difference of opinion among them, as to their cause or causes.

The prevalence of annual fires which burn off the tops of the grasses without destroying their roots, while fatal to young trees, has been thought by some persons a sufficient cause for the prevalence of grasses and the exclusion of trees from the western prairies, but this cause is certainly inadequate. One great cardinal fact will arrest the attention of every discriminating person who attempts the solution of this problem, and that is, that our continent is divided into great longitudinal belts of forest, which are separated by belts of nearly equal width, over which the vegetation is herbaceous, except where desert. These belts are—1st,

the forest-covered region extending from the Mississippi to the Atlantic, —2d, the plains, grass-covered from near the Mississippi to the Rocky mountains, in which the timber is confined to the margin of streams, —3d, the Rocky mountain belt of timber,—4th, the interval between the Rocky mountains and the Sierra Nevada, generally without trees or grass,—5th, the Sierra Nevada, timbered,—6th, the California valley, prairie, with timber along the streams,—7th, the Coast mountains, timbered. If now we examine the rain-fall of these different belts, we shall find that it is closely connected with the vegetation of the surface. The eastern half of the Mississippi valley and the Atlantic slope are well watered and well wooded. The annual rain-fall here varies from 32 to 60 inches. On the plains the rain-fall is not more than half what it is east of the Mississippi, or from 10 to 30 inches per annum. The Rocky mountain belt is well watered as is shown by the flow from it, of nearly all the great rivers of the continent, and this is generally well timbered. The great basin has from 2 to 16 inches of rain-fall, too little to support either grass or trees, except upon the mountain heights. The Sierra Nevada forms another well-wooded and well-watered belt. In the Californian valley almost no rain falls from May to November; the supply of water is limited but sufficient for annual plants. The chief streams are permanent and these have belts of timber along their banks. Others are intermittent, becoming dry *arroyos* in mid summer and on these the timber reaches no further than the water flows. The Coast mountains are again well-watered and well-wooded. All these facts prove that great climatic causes underlie these marked differences in the distribution of vegetation, and make the fire theory simply puerile. That the area of the prairies has been locally enlarged by fires is no doubt true, and where this cause has operated there is no doubt that the artificial propagation of trees will be successful. The fact, however, that trees have grown unexpectedly well on the prairies of Illinois, Wisconsin, Iowa and Kansas, is by no means the demonstration that some have considered it, of the fallacy of the view now advocated. Doubtless by artificial aid the forest, protected from fires and propagated by planting, will rapidly and somewhat extensively invade the grass-covered area, and the forest will itself be, to a certain degree, creative of the influences which promote the growth of trees; by favoring absorption and retarding evaporation and drainage. But those who boast the possibility of covering, at once and anywhere, the prairies of the west with an artificially propagated forest, should remember that the life of a tree continues through centuries, and that to secure the permanent, healthful growth of forests, trees must enjoy, not so much a profuse as a constant supply of water. Those who know anything of the climate of the prairie belt, know that it is charac-

terized by a *deficiency* of *winter rain* and snow, and by occasional though rare seasons of excessive dryness. The want of winter rains to deeply saturate the ground gives to the superficial hybernating grasses,—which may be said to *live* upon the almost copious summer rains,—an advantage over trees equivalent to a victory.

In the periods of extremest drought known to the whites or reported by the Indians and Spanish colonists, no rain is said to have fallen over considerable areas for one and even two years. If, now, one of these extremely dry terms should fall anywhere within the limits of the life of a tree, it would be killed by it, whether at its tenth or hundredth year, and all its fellows would die with it; and then if nature is unaided, the process of forest extension must begin again, far off at the margin of the grassy area. If we refer to the records of observations made within our own State through a period of fifty years, as we can do, we shall find that the annual rain-fall has varied at Marietta from 32 to 62 inches, at Cincinnati from 31 to 65 inches—in each case more than 30 inches. Now, our forest growth can endure this minimum, occurring as it does rarely, and among years in which the rain-fall averages fifty per cent. greater; and, indeed, trees would grow on favorable soils with a constant annual rain-fall not greater than this minimum. But at least twenty inches of rain are necessary, steadily and constantly supplied, for the health and vigor of a mixed forest growth. The rain-fall of the plains does not average more than twenty inches. In eastern Kansas it is thirty. If now, the variations in annual rain-fall were to approach there what they have been with us, it will be seen that the minimum of precipitation could hardly fail to be fatal to a large part of the forest growth. Hence we shall only know, after some hundreds of years of trial, how difficult or how easy it may be to overcome by art the impediments which nature has opposed to the growth of trees on the prairies. Before leaving this subject, I should mention that Prof. Daniel Vaughan, of Cincinnati, published an article "On the Origin of Prairies," in the June number of the "Cincinnatus" for 1856, and another "On the Growth of Trees in Continental and Insular Climates," in the report of the British Association for 1860. A synopsis of his views will be found in the "Annual of Scientific Discovery" for 1860.

Another paper of interest on the distribution of our forests was written by Dr. I. G. Cooper, and published in the annual report of the Smithsonian Institution for 1859. Both these writers take the view that the presence or absence of trees is dependent mainly upon the rain-fall.

TOPOGRAPHICAL FEATURES.

The topographical features of Ohio, upon a general view, are exceedingly monotonous. Though having an area of 36,964 square miles, our State forms but a small part of the great topographical district which includes it. To any one raised sufficiently above the surface, and gifted with superhuman vision, the area reaching from the Lakes to the Gulf, and from the Alleghanies to the base of the Rocky Mountains, would seem to be a level plain, with nothing whatever to break its monotony. Toward the Rocky Mountains the surface of this plain gradually ascends, but at the rate of only something like seven feet to the mile, an inclination wholly unappreciable to the eye. The lakes which are situated in the northern part of our territory, though remarkable geographical features, give little variety to the relief of the surface, inasmuch as they lie at nearly the same level, and are surrounded by shores that rise little above them. Our majestic rivers, too, which make so grand a show upon our maps, and afford so important a system of internal navigation, are accompanied by no imposing topographical features, and, though many of their valleys possess great beauty, it is beauty of a quiet kind, and never such as inspires wonder or awe in the beholder. This topographical monotony, while to the artist and the traveler it may seem uninteresting, and to be regretted, is linked to a degree of universal productiveness, which to the sober judgment is more than an equivalent for all its lacks. Such is the uniformity and fertility of the great surface, part of which we inhabit, that we might almost say that the plough can be driven from the Alleghanies to the Rocky Mountains, from the Lakes to the Gulf; and throughout all these thousands on thousands of square miles there are almost none that are not capable of supporting even communities of inhabitants. Hence, since the wild, the picturesque and the sterile can be easily reached on either hand, that is a kind Providence which has brought the indispensable to national and individual prosperity within easy reach, and has removed the merely æsthetic to localities remote and yet accessible to those who will most enjoy and profit by it; so that it is still capable of supplying its important element to our national culture.

Harmonizing with the prevailing character of the much greater area to which I have referred, the topographical features of our State are, as a general rule, eminently utilitarian. The Ohio is a magnificent stream, and it flows in a valley so charming that it was named by the early French explorers "*La belle riviere.*" Its banks, seen from the river, appear to form bold and often precipitous hills of six or seven hundred feet in

height, so that to one navigating this stream it would seem that our scenery, if without the grand, yet abounded in the picturesque. But it is true that in common with the valleys of all our rivers, the trough of the Ohio is excavated in a plain, and the somewhat striking features which it presents are all the result of the erosion of this plain, which, still unbroken, forms the larger part of our area. North from the Ohio, the plateau has been excavated to form the broad valleys of the Miami, the Scioto and the Muskingum, where the graceful curves of outline, the rich tints of the surface and the evidences of exuberant fertility, combine to form pictures which one would go far to find surpassed. The shores of Lake Erie are usually low and monotonous, but its sea-like expanse of water, bounded by no visible shores, inspires in some degree that sense of the grand and unlimited which clings to every portion of the ocean's shore. The group of islands in Lake Erie offer an agreeable contrast to its prevailing monotony; though too low to be impressive, they exhibit such variety and beauty as rarely fail to charm any of the thousands who now make them places of summer resort.

The courses of our streams show at a glance that a water-shed crosses the State from northeast to southwest. This water-shed forms a range of highlands that slope by long and easy descent to the Ohio on the south, more rapidly to the lake on the north. This divide is a part of the southern rim of the basin of the great lakes, and that which separates the river systems of the St. Lawrence and the Ohio. Though in one sense so important a topographical feature, this water-shed in its relief is almost insignificant, its average altitude being only 500 feet above the lake, its highest point rising perhaps 1000 above the bottom of the valley of the Ohio. Our topographical features may therefore be described as those of a plain, slightly raised along a line traversing it from northeast to southwest, and worn in the lapse of time by the draining streams into broad valleys which impart a pleasing variety to the surface, afford free and healthful drainage, and yet leave unimpaired all the productiveness of its original monotony; in fact, exhibiting perhaps the most perfect adaptation to the wants of man which any surface affected by such climatic influences can present.

On succeeding pages will be found profiles of all the principal railroads and canals of the State, and these furnish at a glance a more complete view of the local topography than could be gathered from any detailed description. It should be borne in mind, however, that all railroad and canal lines are lines of lowest levels, and do not fairly represent the variations of altitude exhibited by the country through which they pass; hence, the summits on all these lines are from 100 to 300 feet below the

topographical summits of the adjacent districts. A few words in generalization or combination of these profiles may not be without interest to one who would acquire a clear idea of the topography of the state.

In the prosecution of the Geological Survey each member of the corps has carried an aneroid barometer to which constant reference has been made for the determination of the altitudes of all important points and for the measurement of the strata composing sections. In these observations the base lines have been railroad stations of which the altitudes were known; and as these bases are so numerous and distributed over so large a portion of the state it has been possible to apply such corrections to the incessant variations of the barometer as have given the results more accuracy than has often been attainable by barometric observations. Oftener than otherwise it has happened that it was possible to start from a point of known altitude and ascend hills of 100 to 300 feet in height and descend again to a known level, perhaps to the starting point, within a few minutes, or, at most, a few hours. Hence littlet ime has been afforded for atmospheric changes, and the observations in the ascent have been corrected by those made in descending. By this means we have accumulated a vast amount of material illustrating the topography of Ohio simply as incidental to our geological work almost without cost to the state, and, as a general rule, sufficiently accurate for all practical purposes. If written out *in extenso* this material would form a volume in itself, but its publication would serve no useful purpose, or, at least, a brief synopsis of the observed facts will meet every want which the mass would supply.

Three profiles across the state from east to west, respectively, near the southern and northern borders and through the center, exhibit the following topographical features: On a line drawn from Cincinnati to Marietta we begin in the excavated valley of the Ohio at low water level 432 feet above the ocean, or 133 feet below the surface of Lake Erie. We are not, however, at this point in the bottom of the Ohio valley, for this, like the valleys of most of our streams, is excavated far below the present channel. Cincinnati is built upon a mass of gravel, sand and clay which partially fills the ancient valley. How thick this valley drift is we have not accurately ascertained, but borings on Mill creek, as well as on the Ohio, show that the bottom of the old excavated channel is not *less* than 100 feet below present low-water mark. In the chapter on Surface Geology these facts are brought into relation with others of similar import, and all are shown to prove a period of continental elevation when all our draining streams were running far below their present levels, and that a subsequent depression of the continent filled these

channels with dead water and caused the accumulation in them of transported materials, sometimes quite to the tops of the banks.

Going east from Cincinnati we rapidly and constantly ascend till the summit is reached of the divide between the waters of the Miami and Scioto. This, on the line of the Cincinnati and Marietta Railroad is passed between Martinsville and Lexington at an elevation of 686 feet above low water at Cincinnati or 553 feet above Lake Erie. In this vicinity the highest summits are isolated knobs such as—

	Above Cincinnati.	Above Lake Erie.	Above Sea Level.
Stultz's Mountain	869	736	1301
Fort Hill	854	721	1286
Bald Mountain	869	736	1391
Long Lick Mountain	822	689	1254
Rapids Forge Mountain	728	595	1160

All these have an elevation above the surrounding country of from 400 to 500 feet. They are composed of the Waverly series at the top, Huron shale in the middle, Water-lime or Niagara limestone at the base, and are outliers of the formations which they contain, separated from the continuous sheets of these formations by excavated valleys, from 20 to 50 miles in width and from 300 to 600 feet in depth. These knobs or mountains afford perhaps the most beautiful landscape views to be found in our state, and are conspicuous monuments of the immense surface-erosion which has taken place in all parts of our area.

Descending eastward from the divide that has been described, we reach at Chillicothe the present bottom of the Scioto valley, the ancient one being much lower. The surface of the Scioto River at this point is 85 feet above the starting point at Cincinnati. Eastward from Chillicothe our profile runs comparatively low for many miles, completing the cross sections of the Scioto valley which reaches as a great trough from Portsmouth, through Scioto, Pike, Ross, Pickaway, Franklin and Delaware counties; in this interval rising about 300 feet. The Scioto valley is bordered on the east by a divide, composed of the hills of the Coal Measures, and which rises to the height of from 500 to 600 feet above Lake Erie. This divide separates the waters of the Scioto from those of the Hocking; the narrow valley of the latter stream being passed at Athens where it has an altitude of 108 feet above Cincinnati. Between Athens and Harmar another and similar divide is passed which separates the valley of the Hocking from the more important one of the

Muskingum. The latter, at its mouth, has an altitude of 130 feet above Cincinnati, or about the level of Lake Erie, and reaches north-west as a marked topographical feature all the way to Massillon in Stark county. At the latter point the stream which traverses it has an altitude of 330 feet above the Lake, but as we know by borings at Dover and elsewhere throughout at least a part of its course, it runs nearly 200 feet above its rocky bed.

In following the line of observation that has been traced, beginning at the west line of Ohio, it will be seen to cross first the valleys of the Great Miami and Little Miami, then of the Scioto, then the Hocking, then that of the Muskingum, all of which have nearly the same north and south direction and reach northward varying distances to the divide which separates the waters of the Ohio, from those of Lake Erie, the southern slope of this divide being drained by the streams which have excavated these valleys. The crest of the watershed having a north-east and south-west direction, the greatest length is given to the most easterly valleys. By deflecting our line of observation slightly to the north, making it terminate in the valley of the Ohio below Wheeling, we shall have added another divide and another trough to the series, all presenting nearly the same features.

If, now, we were to take another line of observation beginning on the western margin of the state near its central line north and south, and moving directly eastward through Sidney, Bellefontaine, Delaware, Mount Vernon, Coshocton and thence to Steubenville, we should meet with the following topographical features: On the line between Darke and Mercer Counties we should be near the summit of the great divide to which reference has so frequently been made, here having an elevation of 600 feet above Lake Erie. Going eastward we should descend into the valley of the Great Miami and above Piqua reach a point only 280 feet above the Lake. Near Bellefontaine we should pass the divide between the Miami and the Scioto, here higher than at any other point,—975 feet above Lake Erie—and formed by an island about 25 miles in length. This island is composed of the Corniferous limestone and Huron shale, once part ot continuous sheets of these formations, now separated from their former connections by an interval of 25 miles on the east and 100 miles on the northwest. Topographically this island corresponds with the "mountains" of Highland County to which reference has already been made. Descending from the highlands of Logan County, at Delaware we reach the bottom of the Scioto valley, here less than 300 feet above the Lake. From Delaware eastward, the country is, for some distance, comparatively level owing to the softness of the Huron shales

which have been broadly and uniformly eroded by glacial and atmospheric action. In Knox County we pass the divide between the Scioto and the Muskingum, called, in its upper portion, the Tuscarawas. Though somewhat broken, this divide is high, its summits reaching an altitude of over 800 feet above Lake Erie. This elevation is due in part to the massive sandstones and conglomerates of the Waverly group which form its geological substructure, and also, in part, to an arch in the strata parallel to the Cincinnati arch but more modest in dimensions. At Coshocton and thence to Urichsville our line of observation runs in the valley of the Tuscarawas, here following a nearly east and west course. Between Urichsville and Steubenville we pass again the high divide which separates the valley of the Tuscarawas from that of the Ohio, the railroad summit being 545 feet, the neighboring hills 800 feet above the Lake. At Steubenville we descend to a point 76 feet above Lake Erie and find here, as elsewhere, the ancient valley of the Ohio cut far below the present stream.

If now, a third line of profile be followed, reaching from Williams County in the north-western corner of the State, through Bryan, Napoleon, Fremont, thence eastward through Erie, Lorain, Cuyahoga, Geauga and Trumbull Counties to the Pennsylvania line, we shall get evidence of a very different surface contour from that which was revealed by our two former profiles. The eastern part of this third line is located on the north-east prolongation of the great northeast and southwest divide, here lower than at most points—363 feet above the Lake—but sufficing to separate the waters of the Mahoning from those of Grand river. Borings made for oil in a great number of localities in the valley of the Mahoning and northward, show that low as the gap now is, it was once much lower, for the ancient stream beds are many feet below the present ones. At the junction of the Mahoning and Shenango which form the Beaver, a depth of 150 feet of gravel and sand fills the old valley to the present surface.

In Geauga County our line of observation crosses a higher portion of the great divide, here forming a table-land more than 600 feet above the Lake. It is underlaid by a thick sheet of the Carboniferous conglomerate which has opposed such resistance to the denuding agents as to cause the relief it exhibits. West of the Geauga plateau the descend is rapid into the valley of the Cuyahoga, which now reaches down nearly to the Lake level, but which, as we learn by borings, was once 250 feet deeper. Emerging from the Cuyahoga valley our line sweeps around parallel with the Lake shore altogether in the Lake basin and constantly diverging from the great divide. At various points it crosses important streams, as Black river at Elyria, the Huron at Monroeville, the

Sandusky at Fremont, the Maumee at Napoleon, etc., and yet none of these streams are flowing in valleys which, in depth, are at all to be compared with those of the rivers that drain the southern slope of the divide. The whole country through which they flow seems to the traveller a somewhat monotonous plain over which the streams meander by circuitous routes and with sluggish currents. The great topographical differences exhibited by the two slopes of the water shed are due to several causes. After the ice had retired from the southern part of the state the Lake basin was still occupied by a glacier which reached far beyond the present water limits, especially to the west and south, and we have evidences that all the country drained by the Sandusky and Maumee was buried beneath a great ice-sheet which moved from the north-east toward the south-west, planing down the surface rocks and producing a large part of the topographical monotony we now observe. This monotony was further increased by a deposition of heavy sheets of clay over the surface from the glaciers or the water that succeeded the ice in the Lake basin. By this clay (the Erie clay) the old channels of the draining streams were filled and obliterated, and the surface smoothed as though by a heavy fall of snow. It should also be said that after the ice had left all Ohio, the northern slope of the divide was for ages covered by the waters of the great inland sea which filled the basin of the lakes, and of this fresh water sea, the divide referred to was, for a long time, the shore. Hence the southern slope of the divide was exposed to surface erosion while the northern slope was being covered more and more deeply with lacustrine sediments. The Ohio and its branches have probably been running in nearly the same valleys they now occupy since the Carboniferous age.

The surface of the Drift deposits which occupy so much of the area under consideration is marked by a series of terraces, and sand, clay and gravel ridges from 10 to 30 feet in height, which deserve mention as topographical features. These ridges and terraces are unquestionably old beach lines, and mark the outline of the lake at different periods in its progressive diminution. Similar ridges to these are now being formed on the south shore of Lake Michigan, and there, as here, a series of more ancient date are found in the interior, running more or less parallel with the present lake shore. The ridges to which I have referred have served in this level country to guide in a somewhat remarkable manner the flow of the draining streams, and it will be seen by reference to the map that the courses of the St. Mary's and St. Joseph's, the Auglaize and the Tiffin bear a peculiar relation to each other and to that of the Maumee. They flow along curves which are rudely parallel with the present shore of

Lake Erie behind the ridges which mark the ancient shore lines, and there is little doubt that these ridges acting as dams or barriers to the direct flow of these streams have compelled them to run for many miles behind them till a common outlet was reached in the channel of the Maumee. At various points along the lake shore we find evidence that the lake ridges have diverted streams from their ancient and natural outlets and have compelled them to form new channels and new mouths.

The courses of some others of our streams present features worthy of note, and such as, I think, can be traced to a common cause. Frequent reference has been made in our reports to the great anticlinal axis that traverses the state from Cincinnati to the Lake shore. This axis forms the divide between the waters of the Scioto and the Miamis; and further north between the Sandusky and Maumee. On the east side of this axis the Scioto, the Sandusky and the Huron flow nearly along the line of strike of the strata, and the same may be said of the Maumee on the west. Hence it is apparent that the direction of the draining streams of the western half of the state has been mainly determinal by the geological substructure. The Cincinnati arch has existed since the Lower Silurian age, and at one time it doubtless formed a sort of low mountain range, broadest and highest at the south. Toward the north it narrowed and vanished, so that while its eastern line is mainly straight—giving directness and polarity to the flow of the Scioto, the Huron and the Sandusky—its western base had a northeast and southwestern bearing, now marked by the strike of the strata and the course of the Maumee.

Till recently it has been supposed that the dip of the rocks underlying the eastern half of the state was uniformly eastward, but in the progress of the survey it has been discovered that this easterly dip, which as a whole is so conspicuous, is locally interrupted by a series of subordinate folds, having the general direction of the Alleghany mountains and of the Cincinnati arch. Owing to the immense erosion which has affected the surface of the state the continuity of the underlying rocks is frequently so broken that it is difficult to trace the folds by which they have been thrown into ridges and valleys, yet, such folds have been observed and over considerable areas are so clearly defined that we cannot only prove their existence but show that they have exerted an important influence upon our surface topography. The nature of these folds will be understood by a few examples. In the northern part of the state the crest of the Cincinnati arch is formed by the Niagara limestone. East of that we have a belt of Water lime which dips rapidly eastward, passing under the Oriskany, Corniferous, Hamilton and Huron: all of which disappear in succession and give place to the Lower Carboniferous or Waverly. In

this Waverly group the Berea sandstone is the most conspicuous feature. It lies near the base of the formation, and we first meet with it near the mouth of Vermillion river. Here its lower surface lies 100 feet above the lake level. Going eastward, at the Amherst quarries it is 141 feet; at Elyria 65 feet, at Berea 140 feet, in the Cuyahoga valley, at the north line of Summit county, 175 feet above the lake. Thus it will be seen that the Berea sandstone rises toward the southeast, instead of dipping in that direction, as we should expect. This reverse dip is probably due mainly to the thinning out westward of the underlying Erie shale, but the eastward rise is not uniform. The strata seem to be lowest about the mouth of the Vermillion river, thence they rise eastward in a series of folds of which the arch of one is west of Elyria, of another a little west of the Cuyahoga. This latter arch is plainly shown on the Lake shore. Between Cleveland and Rocky river, the strata dip westerly more than 60 feet. Thence after a nearly horizontal interval they gradually rise and at Avon point are dipping easterly. So, further south, in Richland county, we find a summit from which the strata dip rapidly eastward to Millersburg. From the valley of the Killbuck they rise over a gentle arch and descend again into the valley of the Tuscarawas at Dover. They gradually rise again toward Carrollton, and then dip rapidly to the Ohio valley. In Coshocton county, in a like manner, after a rapid easterly dip from Newcastle to Coshocton, the strata gradually rise eastward from Coshocton to Newcomerstown, descend to Port Washington, rise gently to Urichsville, then, with perhaps an intermediate fold descend to the Ohio. From these and other facts it appears that the north and south draining streams generally follow the lines of the synclinal troughs; apparently indicating that the direction of the water courses was determined by the folds of the strata of a very remote period in the past. Subsequent erosion, in many instances, changed the lines of lowest level, and of the streams, but except where acted upon by heavy masses of ice, the surface would be likely to retain any impression made upon it, and lines of drainage would be deepened rather than obliterated.

Further observations will be necessary before the folds observed at many different points can be so connected as to determine their north and south extent, and before the system which they form can be fully made out. This will be a work of considerable difficulty as the rocks we need to examine are in so many places covered and concealed. It is a subject, however, of much geological interest, and it is to be hoped that it will receive attention from future observers. It seems to me probable that it will be discovered that a large part of the sinuosity exhibited by the lines of outcrop of the Coal Measures and the Conglomerate, as well

as many somewhat conspicuous features in our surface topography may have resulted from this series of folds to which I have alluded. For example: the Geauga plateau is traversed by a geological arch and is bordered by inconspicuous and yet evident synclinal troughs in which flow the Cuyahoga and Grand rivers. Over this plateau the Conglomerate is of unusual thickness, and its mass, by resisting erosive agents, may have been the cause of the relief it presents, and the prolongation upon it of the long tongue of Coal Measure rocks. It is probable, however, that the position of the rocks aided to some degree their composition in resisting, or, at least, diverting erosion. It is possible, also, that the marked fold of the coal strata seen in Carroll county, and traceable further north along the topographical divide may accompany that divide through Portage and Geauga and form its real foundation. So, too, the Medina plateau, also floored with Conglomerate, and carrying its prolongation of the Coal Measures in part at least owes its existence to a geological arch passing north and south between the valleys of the Cuyahoga and Black rivers. This arch may be identical with that which separates the waters of the Killbuck from those of the Tuscarawas. In western Holmes and eastern Richland we have a westward projection of the Coal Measures and also a geological summit. Here, too, these phenomena may be intimately connected, and the synclinal valley of the Killbuck and the summit west of it may be traceable to a considerable distance north and south. Possibly these questions may be settled before the completion of the geological survey.

As to the age of these folds it seems pretty certain that since the Coal Measures are all affected by them they are of a date posterior to the Carboniferous period; and were, therefore, formed long subsequent to the upheaval of the Cincinnati arch. They are probably synchronous with the main folds of the Alleghanies and are simply a continuation westward of the system of subordinate folds of the same date which traverse western Pennsylvania and have been described by the Pennsylvania geologists.

HIGHEST LAND IN THE STATE.

It has not yet been certainly determined which is the very highest point in the state of Ohio, but so far as our observations have extended, the highest land has been found in Logan County. Mr. F. C. Hill has carefully measured, by the level, the altitude of the highest summit on the divide between the headwaters of the Scioto and Miami, in Logan county, and has found that this point is 195 feet higher than what has been represented as the highest land in the state.

The altitudes of a few of the highest summits which have been measured by the present geological corps are given below. Others will be found in Appendix B:

	Above the Sea.	Above Ohio River.	Above Lake Erie.
1. Summit between Scioto and Miami, in Logan county, probably highest land in the state ..	1540	1108	975
2. Highest hills of Richland county....................	1475	1043	910
3. Round Knob, Columbiana county	1409	977	844
4. Mt. Tabor, Tuscarawas county.......................	1365	933	800
5. Stultz's Mountain, Highland county...............	1301	869	736
6. Long Lick Mountain....................................	1254	822	689

SUMMITS AND PASSES OF THE WATER SHED.

Two canals and a number of railroads cross the great divide which separates the waters of the Ohio from those of the Lake basin, and the profiles of these lines, given in Appendix B, show the general contour of the surfaces of the state in a north and south direction. As has been remarked, however, all these public works follow carefully chosen lines of lowest level, and give but an imperfect view of the relief of the water shed. The actual crest of the divide forms a singularly tortuous line, which exhibits at different points remarkable variations of altitude. For example, beginning on the Pennsylvania line, east of Ashtabula county, the headwaters of the Shenango reach within ten miles of Lake Erie and drain a surface which has an altitude of over 600 feet above the lake. Thence the crest of the water shed strikes south-westerly through Ashtabula and Trumbull, falling down to a level of 363 feet at the summit of the A., Y. & R. R. R. in Orwell. Thence it sweeps with a sharp curve, nearly at the same horizon, around the head waters of Grand river far down in Trumbull. Here it turns almost due north, coming again within ten miles of the lake in the northern part of Geauga and attaining near Chardon an altitude of 750 feet. Thence it runs due south through Geauga, east of the Cuyahoga river; passing near Ravenna in the center of Portage, thence on to Hanover summit in south-western Columbiana and north-eastern Carroll; whence it returns with a north-westerly course to Akron. In this interval between Chardon and Akron it is crossed by the C. & M. R. R. in Mantua, at an altitude of 590 feet; by the A. & G. W. R. R. in Freedom, at an altitude of 613 feet; by the C. & P. R. R. at the Hanover summit at a height of 606 feet above the lake; the tops of the adjacent hills along the line rising from 50 to 100

feet above the railroad summits. At Akron, Summit lake, which lies on the divide and forms the summit level of the Ohio canal, is 395 feet above Lake Erie. From this point the crest of the water shed runs nearly due west along the north line of Wayne, Ashland and Richland. In Wadsworth, Medina county, it passes over an outlier of the Coal Measures; the local summit of the A. & G. W. R. R. having here an altitude of 600 feet, and the neighboring highlands 680 to 700 feet. Following the crest westwardly from this point, we descend into the gap drained by the head waters of Black river, which flows into the lake, and the river Styx, a tributary of the Tuscarawas. Through this gap passes the Tuscarawas Valley R. R. at an altitude of 382 feet above the lake level. From this gap to Crestline, the summit of the divide is uniformly high—nowhere less than 600 feet—the highest point on the line of the A. & G. W. R. R. being at Ontario, where it crosses the crest at an elevation of 802 feet. The highest summit in the vicinity reaches an altitude of over 900 feet, and forms one of the highest points in the State. At Crestline—the summit of the C. C. & C. R. R.—the crest of the water shed has an altitude of 600 feet. Thence it passes south-westerly through Crawford and Marion, and thence north-westerly through Hardin. At the west side of this county turning again south-west, it throws off a lofty spur into Logan, but the main line continues south-westerly between Auglaize and Shelby, through the corner of Mercer and northern part of Darke into the state of Indiana. The altitudes along the line we have followed, after leaving Crestline, are generally above 600 feet. The summit level of the Miami canal at St. Mary's is, however, much lower, being only 367 feet. This, therefore, like those in Medina, Summit and Trumbull counties, is a great notch or water-gap in the divide. The crest of the divide on either side of the St. Mary's channel, rises above 600 feet. Where it crosses the Indiana line, at Union City, the track of the B. & I. R. R. has an elevation of 615 feet, the adjoining highlands being 50 feet higher.

The spur of the water shed which occupies the interior of Logan County is a topographical feature worthy of notice. As has been before remarked, this constitutes the summit of the divide which separates the waters of the Miami from those of the Scioto and Sandusky. The depot at Bellefontaine is 642 feet above the lake, while the highlands lying east of this point rise over 300 feet higher. This elevated region is the island of Devonian rocks which I have mentioned on a preceding page.

In the chapter on Surface Geology I shall have occasion to refer again to the deep notches or water gaps which I have described as cutting through the great barrier that separates the basin of Lake Erie from

that of the Ohio; namely, the St. Mary's gap which connects the valleys of the Maumee and Miami; those of Medina and Summit, which connect the valleys of Black river and the Cuyahoga with that of the Tuscarawas; and the Trumbull gap which leads from the valley of Grand river to that of the Mahoning. I will venture, however, now to call attention to some facts connected with these gorges which seem to me to have special interest and significance as related to the system of erosion which has given character to our topography. In the first place, the almost absolute identity of level which the gaps present will strike the most casual observer, and will not fail to suggest their reference to a common producing cause. I think it would not be difficult to show that each of these gaps has served as a waste weir, through which a portion of the surplus water of the Lake basin has been drained off into the Ohio. Each of these lines of drainage will be found to be marked by unusual accumulations of rolled and transported material, such as would be the natural product of a copious flow of water continued through ages of time. Whoever has passed up through the valley of the Miami must have had his attention drawn to the great masses of local drift with which it is obstructed. This drift is largely composed of rounded pebbles of the limestones which form the highlands bordering the upper part of the valley, and doubtless represents the material which once filled the gorge, opened northward through the water-shed. The more easterly gaps present the same phenomena. From the great bend of the Cuyahoga a belt of gravel of unknown depth reaches southward through Stark County, forming a geological and topographical feature, which will be found described in the report on that county. The accumulations of drift, in the valley of the Beaver and in that of the Ohio near the mouth of the former stream, is so unusual that Mr. Morris Miller, who has written upon the surface geology of this region, was much struck by it, and could only account for its existence by supposing it to be the product of a great flood bursting through the gap I have described. The rolled and rounded condition of the gravel and boulders which compose this mass of drifted material forbids, however, the supposition that they could have been produced by any cataclysm, and plainly records the action of a steady flowing, though powerful stream. It should be said, also, that the rocky bottoms of these gorges are deeply buried, and that the erosion which produced them began before the ice period, and was mostly accomplished during an interval of continental elevation. They were subsequently more or less perfectly filled by the deposits of the Drift and have again been partially cleared by the erosions of the modern or recent epoch.

Perhaps we shall better understand the manner in which these gorges were formed if we keep in mind the facts that the basin of Lake Erie has been filled, first, with ice which extended over the southern rim and as far south as Cincinnati; that subsequently it was occupied by water which reached at least to the height of these gorges; and then, after an interval which permitted the growth of a forest and the accumulation of soil over much of the old glacial area, a more complete submergence carried the water level high enough to permit icebergs to float through these gaps into the basin of the Ohio and drop their loads of boulders on the top of the sediments deposited before. When a subsequent continental elevation emptied the Ohio valley of the water that had filled it, there must have been a copious flow from the lake basin through every line of drainage until each was left above the water level. As we know by the series of terraces and lake ridges which run in parallel lines over the surface lying between the Lake shore and the summit of the water shed, the present outlets of the Lake basin were so obstructed—possibly by ice—that the water was high enough to discharge itself through these gaps. In the process of time, remote and lower outlets drained off the water. Its surface level was depressed, until the one great inland sea was divided by lower barriers into our existing chain of lakes. Long intervals of time elapsed, however, before the present condition of the Lake basin was reached. The contraction of the water surface took place very gradually, or rather, it remained for long periods stationary at different and successively lower levels. Each of these periods has left its indisputable record, somewhat obliterated by time, but scarcely less easily traced than would be the outline of the present shore, with its cliffs and beaches, if the barrier of Niagara were cut away and the water level depressed another hundred feet.

A more recent water gap—yet very ancient—apparently similar in character to those I have described, but at a lower level, is that which connects the valley of the Maumee with that of the Wabash. This will be found described in detail by Mr. G. K. Gilbert in another chapter of this volume. From his description and map we learn that when the water of the lake stood about 250 feet above its present level, a great river, comparable with the Niagara, flowed from it where Fort Wayne now stands, cutting a broad and deep valley through rock as well as sand and gravel, and discharging itself into the Wabash. After flowing thus, for ages, this river—which never had a name and no man ever saw—ran dry and ceased to be, for by the cutting down of some other outlet, or the warping of the crust of the earth—that type of instability which we call *terra firma*—the surplus water of the lakes was drained in another direction, never more to flow across the surface of our State.

LAKES AND PEAT SWAMPS.

Owing to slight irregularities in the surface of the Drift deposits in the northern counties of the state, there were here formed innumerable little water basins. In many instances these are filled up with vegetable growth and are now swamps or peat bogs. These peat marshes support a somewhat peculiar vegetation in which are many orchids and other plants, said by Prof. Gray to range "from Massachusetts to Michigan and northward." In a vast number of instances the basins I have described are still occupied with water, and form a series of lakelets which constitute a striking and in many instances a very charming feature of the topography of a belt bordering the crest of the great divide. Within a circle of twenty miles radius drawn around a point, where I formerly resided in Summit county, I mapped nearly one hundred of these little lakes. This series of water basins, either lakes or swamps, may be said to characterize the highlands of the water-shed throughout, not only its entire line within our state, but its prolongations into Pennsylvania, New York and Michigan. Chautauqua lake, Conneaut lake and the Pymatuning swamps are members of this chain of water-basins which mark the summit of the divide in New York and Pennsylvania, while in Michigan the number of lakelets it bears is almost countless. The presence of these basins on the crest of the water-shed has, before this, attracted attention, and much surprise has been expressed that the highest lands in the state and the summit of the divide from which all our streams flow, should be so much less perfectly drained than the low lands and the slopes. This will be found to be a characteristic, however, of most topographical summits which have any considerable breadth of surface, and the solution of the problem is not a difficult one. The lower portions of the slopes of every water-shed receive the drainage of all that lies above them, the force of the draining streams is there cumulative, for the volume of the water which passes over the surface exceeds, perhaps, ten times that which falls upon it. Hence every barrier is burst or cut away and continuous lines of drainage are formed which cut down the margins and completely empty such water basins as may have originally existed there. It will be readily seen that if the Pymatuning or Bloomfield swamps, or any of the many lakes, upon the summit of the water shed, were placed so far down the slope as to receive, in the season of rain, the drainage of large areas lying above them, such floods of water would pour into them as to overtop their margins and rapidly and effectually cut down any barriers that opposed their complete drainage. They would also be the receptacles for most of the solid material trans-

ported by the streams draining them, and thus, by the two processes of cutting down of their margins and filling their basins, they would soon cease to be either lakes or swamps, and become areas of well-drained and perhaps, in time, of upland soil. On the summit of the water shed, however, depressions of the surface receive only such water as falls in or immediately around them. The supply comes, for the most part, in brief showers or continued gentle rains which create no surplus that cannot escape, either by some little rill, which with almost no eroding power flows ever the lowest point of the margin, or by slow percolation through the porous material of their banks or the fissures of the underlying rocks. These basins are the sources of most of the springs which flow out at lower levels, supplying cool and filtered water in gushing fountains in localities which are made more attractive and habitable by them. These cisterns on the highlands are, therefore, among the most useful features in our topography, and if by any means they should be drained, a long train of resultant evils would be experienced by the inhabitants.

THE BASIN OF LAKE ERIE.

I have already described most of the topographical features which have resulted from surface erosion and have referred them to their producing cause, so that it may seem that little more need be said with the purpose of creating an appreciation of the nature and the magnitude of the effects this cause has wrought upon our topography. It is true, however, that the most important topographical feature and the most stupendous monument of erosion found within our limits, has not been alluded to in this connection. I refer to the basin of Lake Erie. So much the larger part of the Lake lies outside of the state of Ohio that it will scarcely be expected that a full and general description of its outlines and structure should form part of any of our state documents. This is the less necessary as the subject is alluded to in the geological reports of our neighboring states and in those of Canada, and the duty of making a careful survey of the Lake and study of the phenomena it presents, has engaged the attention of a corps of engineers connected with the War Department for many years. When this survey shall have been completed and the results published, the public will undoubtedly have so comprehensive and yet minute and accurate a presentation of the subject as will leave nothing more to desire in this direction. Pending the completion of the great work to which I have referred it has seemed to me unwise to attempt any new observations on the topography, properly speaking, or to gather the miscellaneous facts already

published, bearing on this subject. I shall limit myself, therefore, to the briefest possible statement of such facts concerning Lake Erie, as are inseparably connected with the subject matter of this report. The present surface level of Lake Erie is about 565 feet above that of the ocean. The vagueness of this statement is necessitated by the remarkable oscillations of level which the lake surface exhibits. These fluctuations have been observed for more than three quarters of a century, and the results of observations continued through more than half a century were published by Col. Charles Whittlesey in the Smithsonian Contribution for 1859. During the years covered by these tables—1790 to 1854—the greatest oscillation of level was 6 feet 8 inches, the lowest stage having been reached in the winter of 1819, and the highest in June 1838. The cause of these oscillations of level is undoubtedly to be found in the variations of annual rain-fall in the region drained by the current which flows through the Lake. The basin of Lake Erie is but a local expansion of the river known in different parts of its course as the St. Marie, the St. Clair, the Detroit, Niagara and St. Lawrence. Like all other rivers, this varies in height, according to the variation of rain-fall on its sources and along its bank.

As compared with the others of the series of great lakes, Lake Erie is shallow, its greatest observed depth being, off Long Point, 202 feet. Its average must be much less, perhaps not over half that. These figures express, however, simply the depth of the water. The depth of its rocky basin has never been ascertained; that it is considerably more than 200 feet below the water surface is proven by the old clay-filled channels which once led into it. Observations made at the Lake end of the new tunnel of Cleveland show that there the rock bottom is covered with nearly 100 feet of clay. There is every probability that a thickness of from 100 to 200 feet of drift clay covers the bottom in the deepest parts of the Lake, which lie towards its eastern end. Most of the west end of Lake Erie is shallow, the intervals between the islands having an average depth of something like 40 feet to the clay bottom, of which the thickness is probably not great, as the islands are composed of solid limestone left in relief through the scooping out, by glacial action, of the intervening channels. We know, however, from the borings made at Detroit and on the western portion of the Canadian peninsula, that a deeply excavated trough connects Lake Huron and Lake Erie, and the line of this trough doubtless traverses the west end of Lake Erie; probably north of the islands.

It is doubtless known to some, who may be readers of this volume, but probably is realized by few, that the basin of Lake Erie in all its

length and breadth—as well as the smaller but yet deeper one of Lake Ontario, and the broader and far deeper ones, of Lake Michigan and Lake Huron—has been excavated by mechanical force from the solid rock. The shores of all these lakes have been carefully examined and have been found to be composed of sedimentary strata, lying nearly horizontal as they were originally deposited. There are many lakes in the world that have been formed by the upheaval of their margins, but our great lakes are none of these. They are plainly basins of excavation, dug out of sheets of rock, which were continuous over all the area they occupy. The southern slope of the lake basin is composed, both below and above the water line, of the cut edges of these strata which once extended all the way across to the Canadian highlands. Any one who will stand on the cliffs which overlook the Lake in northeastern Ohio—cliffs which now rise 750 feet above the water surface—and will look over the sea-like expanse toward the Canadian shore, too distant to be visible, will get some realizing sense of the vastness of the mechanical effect which has been produced here, and an appreciation he could hardly obtain elsewhere, of the resistless power of the agents which accomplished it. Of what these agents were and how they acted, some evidence will be given in another place; but I may here say that they were unquestionably the same that have produced all the great monuments of erosion seen elsewhere, *water* and *ice*, and of the two, that which was by far the most potent and that which alone could excavate broad, boat-like basins, such as these, was *ice*.

CHAPTER III.

THE GEOLOGICAL RELATIONS OF OHIO.

The geological structure of Ohio, like its topography, is so far part of a great whole that it cannot be intelligently considered without reference to its relations. The rocks which come to the surface within the limits of our State constitute a portion of the series which forms our continent; and the belts and areas underlaid by the outcrops of the different formations are so connected with the extension of these areas into other states that it is quite necessary for the full comprehension of our geology, that some knowledge should be had both of the general principles of geological classification, and of the structure and geological history of the North American continent.

Probably some of those into whose hands this report will fall, will be in possession of this preliminary knowledge; but, as it is the primary object of the Geological Survey to benefit the people of Ohio, and there are doubtless many of these to whom the subject will be comparatively new, I have thought best to introduce as a preface to a detailed description of the geological structure of the state a brief *resume* of such facts as have an inseparable connection with those which we have brought or may yet bring to light.

The labors of those who during the last two hundred years have devoted themselves to the study of the structure of the globe, have resulted in the creation of the science of Geology; and the claim which this department of human knowledge has to the name of science, depends upon the symmetry which has been found to prevail in the arrangement of the materials composing the earth's crust. By the slow process of adding fact to fact and by comparing the observations of the devotees of the science in different lands, it has been found that the rocky strata of the earth hold a definite relation to each other in position and hence in age; that many of them are distinguished by constant or general mineral features, and contain characteristic or peculiar remains of plants or animals by which they may be recognized wherever found. This

sequence of deposits forms what has been termed the Geological Column, and the changes which are recorded in the strata of different formations both in regard to the physical condition of the earth's surface, and the organic forms that inhabited it, constitute what is known as Geological History. Of this record the different ages, periods and epochs follow each other everywhere in regular order, and form a grand and uniform system of change and progress, compared with which the successive eras of human history shrink into insignificance.

The facts which geology supplies appeal not only to our appreciation of the grandeur, order and symmetry of the universe and to our sense of beauty in created forms, but they have an immediate and practical bearing upon the material wants of society, and have contributed perhaps more largely than any other cause to the progress which humanity has made in intelligence and happiness within the last two hundred years. From the connection of geology with agriculture, mining and manufactures, it may be said that in its different branches this science lies at the foundation of our modern civilization; inasmuch as the occupations, the wealth and power of communities and nations in many, we may perhaps say in most instances, depend directly upon the character, structure and resources of that portion of the earth which they inhabit.

The observations of geologists have shown that the materials which compose the earth's crust form three distinct classes of rocks, the *igneous*, *sedimentary*, and *metamorphic*. Of these, the first class includes those that are the direct product of fusion. These are divided into two subordinate groups, *volcanic* and *plutonic*, of which the first includes such as are produced by volcanic eruption, *lava* in its different forms, *pumice*, *obsidian*, *trachyte*, etc. The second class of igneous rocks,—the plutonic—comprises those massive rocky forms which are without distinct bedding, have apparently been completely fused, and yet were probably never brought to the surface by volcanoes. Having consolidated under great pressure, they are dense and compact in structure, never exhibiting the porous and incoherent condition which is so characteristic of the purely volcanic rocks. The plutonic rocks are *granite* in some of its varieties, *syenite*, *porphyry*, and part, but not all, of *basalts*, *diorites* and *dolerites* (greenstones). None of these igneous rocks are found in place within the State of Ohio, though they exist in vast quanities in the mining districts of the West, and on the shores of Lake Superior. From the latter region numerous fragments were brought to us during the Glacial period, and they constitute a prominent feature in the Drift deposits that cover so large a part of our State.

As we have abundant evidence that our globe has been consolidated

from a gaseous through a liquid condition, and that the consolidation was the result of the cooling of an intensely heated mass, we may suppose that the igneous rocks were those first formed, and that they constituted the primeval continents. As soon, however, as these rocks were exposed to the action of the elements, they began to be worn down and washed away, and the materials derived from them were deposited as sediments in the first existing water basins. That process has been going on through all subsequent ages, so that by far the larger part of the rocks which we now encounter in our study of the earth belongs to the class of *sedimentary* deposits. These are known to us as *sandstone*, *shale*, *limestone*, etc.; the consolidation of the comminuted material having been effected by both chemical and physical agencies. The differences which we discover in these sedimentary rocks are, for the most part, dependent upon very simple causes, such as we now see in operation upon every coast. The showers that fall on the land give rise to rivers, and these on their way to the sea excavate the valleys through which they flow, transporting the materials taken into suspension to the point where the motion of their currents is arrested, and their power of suspension ceases, that is, in the water basins where they debouche. In the gradual arrest of the motion of river currents, the coarsest and heaviest materials first sink to the bottom, then, in succession, the fine and still finer, until all are thrown down.

Shore waves are still more potent agents in the distribution of sediments. Whether they break on cliff or beach they are constantly employed in grinding up, and by their undertow carrying away, the barriers against which they beat. Nothing can resist their force and ceaseless industry. In time the most "iron bound" coast and the broadest continent are swept away in their slow but sure advance, and the comminuted materials are spread far and wide in the rear of their line of progress.

Rain, rivers and shore waves are the great destructive agents in geology—the greatest levellers known—but in the same measure that they demolish, the sea builds again. She sifts, sorts and spreads anew and in regular order, the materials she receives from them, thus laying the foundations of new continents. These, when raised above the sea-level by internal forces are again cut away, again to be rebuilt.

If we desire to observe the processes of continent making, we have only to notice what is now taking place everywhere along the sea margin. On every shore where the wash of the land accumulates we shall find a deposit of gravel and sand which forms the beach; a little off shore, a belt of finer sand; while in the depths of the ocean are deposited only

organic sediments. These latter are mainly carbonate of lime which before held in solution was absorbed and secreted to form the hard parts of organisms, mostly microscopic, which inhabit the open sea. This is no fancy sketch. The soundings of the Coast Survey, and those made preparatory to the laying of the ocean cables have shown that the bottom of the Atlantic, off our eastern coast, is composed of the materials I have described arranged in the belts I have enumerated, viz., the first of gravel and sand composing the beach and sea bottom immediately adjacent to it; then a belt of finer sand and clay; outside of that, and everywhere beyond the depth of 600 feet, a calcareous deposit of organic origin. When consolidated, these materials form rocks with which we are all familiar; the gravel, conglomerate; the sand, sandstone; the clay, shale; the calcareous organic sediment, limestone.

We have also, everywhere evidence that what we know as *terra firma*, is a type of instability; that all lands are constantly undergoing changes of level, and that over all our continent the sea has rolled, not once, but many times.

The triturating effect of shore waves has been described and can be witnessed on every coast. In the submergence of a continent, all portions of its surface must in succession come under the influence of this agency. By its action the solid and superficial materials lying above the sea level, the rocks, sand, gravel and soil would be ground up and washed away, the greater part forming mechanical sediments and distributed according to the law of gravitation, the soluble portions taken into solution and carried out to impregnate the ocean waters and to supply material to the myriads of organisms that have the power to draw from this solution their solid parts. In the advance inland of the shore line, the first deposit from the sea would be what may be termed an unbroken sheet of sea-beach, which would cover the rocky substructure of all portions of the continent brought beneath the ocean. Over this coarser material would be deposited a sheet of finer mechanical sediments, principally clay, laid down just in the rear of the advancing beach; and finally, over all, a sheet of greater or less thickness of calcareous material, destined to form limestone when consolidated, the legitimate and only deposit made from the waters of the open ocean.*

Upon the retreat of the sea, the surface of the land would be again covered with vegetation, acted upon by atmospheric erosion, washed into

* Local circumstances would modify this order of superposition, and sandstones shales and limestones would often shade into each other, sandy-shale connecting the sandstones and shales, earthy-limestones the shales and limestones; as we so frequently find them doing. The order of sequence is here stated in its simplest form.

hills and valleys, and locally covered with sand or clay, the products of this local washing. Any excavations, now made upon this continent, would reveal distinct and legible records of this last inundation, viz., beneath the superficial materials, a limestone ; below this, a shale ; below that a sandstone, or conglomerate ; and all these resting upon the rocky foundations of the continent; the result of a previous submergence, and representing an earlier geological age. The later strata would be found laid down over all the irregularities of the older surface, and between the older, and more recent rocks a break, or want of continuity, and generally a want of harmony in their lines of deposition ; or, as geologists say, they would be *unconformable*.

Another invasion of the sea would leave similar records of a similar history, with this difference only, that the tribes of animals and plants inhabiting the land and water would, in the lapse of ages, have experienced marked changes. Perhaps in the interval the old fauna and flora would have entirely disappeared, and others have succeeded them, so that the new sediments would include only relics of the new races.

Such, in few words, is the order of the events that have given rise to most of the phenomena of geology, and this will serve to explain how it happens that we so frequently find sandstones and conglomerates followed by shales or soft, clay rocks, and these again overlaid by limestones; and, that in the different strata we have different groups of fossils. In the sandstones and conglomerates which are the direct *debris* of the land we naturally find almost nothing but the remains of terrestrial plants ; these often in great abundance, not unfrequently accumulated in confused masses of broken trunks, leaves and fruits, such as form the heaps of driftwood upon our shores. In the limestones we find mainly the remains of marine organisms, corals, shells, crustacea and fishes.

All the rocks of Ohio belong to this class of sedimentary strata, and include abundant examples of each subdivision of the two great groups, the mechanical and the organic sediments.

Still another kind of deposits needs to be mentioned in order to complete the list of sedimentary rocks, namely, the *chemical*, but these take little part in continent-making and so require but a passing notice in this sketch. The chemical deposits are such as have been plainly precipitated from chemical solution and include rock-salt, gypsum, materials which form mineral veins, and those deposited by mineral springs—calcareous tufa, travertine, &c.—beds of ochre and iron ore. Some of these owe their accumulation to the action of organic matter, but not having distinctly formed any animal or plant tissue they cannot be classed as organic sediments.

In all parts of the world rocky masses are met with which would not

at first sight be referred to either of the classes I have described. These are usually found in sheets of greater or less thickness, resting in regular sequence one upon another, as though they had once been sediments, but now upheaved and contorted—sometimes standing nearly vertical—and greatly changed both in their structure and texture. These form a class which have been designated as the *metamorphic*, or changed rocks. They compose most mountains and have been hardened and made crystalline by the forces that have acted upon them in their upheaval; they usually bear evidence of having been highly heated, and in some cases even fused in the process; so that some of them can hardly be distinguished from members of the class of igneous rocks.

These metamorphic rocks form all of the mountain *chains* of our country, the Alleghanies, the Rocky mountains, the Sierra Nevada, and the Coast ranges, and they underlie most of New England and much of Canada. They consist of certain *granites* and *diorites*, *gneiss*, *mica slate*, *clay slate*, *marble*, &c. Of these rocks also, we have no representatives in Ohio except such as have been brought to us by the Drift agencies.

These, then, are the *materials* with which we have to do in the study of the generalities of our geology. And now a few words in reference to their arrangement. I have said that the sedimentary rocks, underlying the earth's surface form what is known as the Geological Column, that is, they are arranged in a regular sequence which holds good over all the earth's surface. It is true, however, that in no one place, so far as has been observed, is every member of this series present: for the reason, that while any one formation was accumulating in a sea basin which occupied only a limited portion of the earth's surface, dry land existed at the same time in great areas and there no sediments could be laid down. *The sea is the mother of continents!* and with the exception of local accumulations in bodies of fresh water, all sedimentary rocks have been formed in oceanic basins.

In order that a clear idea of the order of superposition which prevails in the rocks that form the geological series may be readily obtained, a chart is given herewith on which all the formations are represented with an enumeration of the principal strata that compose them under the names by which they are commonly known in this country, with their European equivalents. The life history of the globe is also indicated in the subdivisions of geologic time into eras, which are marked by the presence or abundance of characteristic groups of animals or plants.

EOZOIC SYSTEM.

By reference to the accompanying table it will be seen that the oldest rocks of which we have any knowledge are those designated by the name of the Eozoic System, consisting of the Laurentian and Huronian groups. These are metamorphic rocks which underlie a broad belt in Canada, extending from Labrador to the Lake of the Woods, and thence to the Arctic Sea. This area, bordering the St. Lawrence, has given the name to the principal subdivision of the formation, the Laurentian. These rocks also form the Adirondacks, a part of the Alleghany belt, the Ozark mountains, and reappear in Texas, the Black Hills of Nebraska, and in some of the mountains of Arizona. Though called the oldest rocks, because they underlie all other members of the geological series, the Eozoic strata are certainly not the first formed rocks of the earth's surface. Those, as has been said, must have been of igneous origin, but the Eozoic group are metamorphosed sediments, granite, syenite, diorite (greenstone), dolomite (magnesian lime stone) clay slate, talcose slate, chlorite slate, beds of magnetic iron, &c. These are arranged in successive strata, once horizontal, but now greatly disturbed, in many instances standing at a high angle with the horizon. It is computed by Sir William Logan that this group of strata attains a thickness of 47,000 feet in Canada, and as we know that all this material has been accumulated from the erosion and destruction of some pre-existent continent, we have in this mass some indication of its extent and altitude. It should also be said that this ancient continent may itself have been composed of the debris of one still older, and we have no means of reaching in this direction the limits of geological time.

The Eozoic System was formerly styled Azoic, or lifeless, because it was supposed that these rocks were deposited previous to the existence of animal or vegetable life upon the globe; but within the last few years evidence has been rapidly accumulating that during the Laurentian ages life did exist in abundance and in various forms. This is inferred from several facts, among which may be mentioned the presence of carbonaceous matter—as anthracite and graphite—which is found in considerable quantities, and which, it is agreed by all chemists, could have been accumulated only through the agency of life. The same thing may be said of the large amount of phosphorus and sulphur in phosphate of lime and sulphide of iron disseminated through these rocks; minerals which are generally the products of organic action; also of the beds of iron ore which probably accumulated as iron ores are now forming and have formed during the more recent geological periods, through the

CHART OF GEOLOGICAL HISTORY.

PREPARED BY

J. S. NEWBERRY.

ERAS.		AGES.		PERIODS.	EPOCHS.	STRATA.		
						(N. America.)	**(Ohio.)**	***(Europe.)***
PSYCHOZOIC.	Age of Angiosperms and Palms.	AGE OF MAN.		HUMAN.	Historical.	Cave Deposits. Peat. Alluvium.	Peat. Alluvium.	*Lake and Cave Deposits.* *Peat. Alluvium.*
CENOZOIC.		AGE OF MAMMALS.		QUATERNARY.	Terrace. Champlain. Glacial.	Terraces. Loess. Saxicava Sand. Forest Bed. Champlain Clay. Erie Clay. Glacial Drift.	Terraces, Beaches. Iceberg Drift. Forest Bed. Erie Clay. Glacial Drift.	*Old Cave Deposits. Terraces.* *Peat. Loess.* *Marine Clays.* *Glacial Drift.*
				TERTIARY.	Pliocene. Miocene. Eocene.	Sumter Beds. Yorktown Beds. { Vicksburg Beds. { Jackson Beds. { Claiborne Beds.	Wanting.	*Crag.* *Molasse. Faluns.* *Calcaire Grossier.* *London Clay, &c.*
MESOZOIC.		AGE OF REPTILES.		CRETACEOUS.	Upper Cretaceous. Middle Cretaceous. Lower Cretaceous. Wealden.	{ Fox Hill Group. { Pierre Group. { Benton Group. { Dakota Group. (Wanting?) (Wanting?)	Wanting.	*Maestricht Beds.* *White Chalk.* *Chalk Marl.* *Upper Greensand.* *Gault* } *Neocomian.* *Lower Greensand.* } *Wealden, Fresh Water Beds.*
	Age of Cycads.			JURASSIC.	Oolitic. Liassic.	Jurassic Strata, Nebraska, Colorado Utah, Nevada, California, Sonora.	Wanting.	*Upper Oolite.* { *Purbeck Beds.* *Portland Stone.* *Kimmeridge Clay.* *Middle Oolite.* { *Coral Rag.* *Oxford Clay.* *Lower Oolite.* { *Great Oolite.* *Inferior Oolite.* *Upper Lias.* *Middle Lias.* *Lower Lias.*
				TRIASSIC.	Keuper. Muschelkalk. Bunter-Sandstein.	Triassic Sandstones, Marl, Coal, &c., Atlantic Coast, New Mexico Arizona, California, Sonora, &c.	Wanting.	*Keuper.* *Muschelkalk.* *Bunter-Sandstein.*
PALÆOZOIC.	Age of Acrogens.	CARBONIFEROUS, OR AGE OF COAL PLANTS AND AMPHIBIANS.		PERMIAN.	Permian.	Permian Dolomites, Kansas and Nebraska.	Wanting.	*Zechstein.* *Rothe-Todt-liegende.*
				CARBONIFEROUS.	Upper Coal Measures Lower Coal Measures. Carb. Conglomerate.	U. Coal Measures. L. Coal Measures. Carb. Conglomerate.	U. Coal Measures. L. Coal Measures. Carb. Conglomerate.	*U. Coal Measures.* *L. Coal Measures.* *Millstone Grit.*
				SUB-CARBONIFEROUS.	Upper Sub-carboniferous Lower Sub-carboniferous.	Sub-carb. Limestone. Sub-carb. { Shales and Sandstones.	Sub-carb. Limestone. Waverly Group.	*Mountain Limestone.* *Lower Limestone Shales.*
		DEVONIAN, OR AGE OF FISHES.		CATSKILL.	Catskill.	Catskill.	Wanting.	*Upper Old Red Sandstone.*
				CHEMUNG.	Chemung. Portage.	Chemung Group. Portage Group.	Erie Shale. Huron Shale.	
				HAMILTON.	Genesee. Hamilton. Marcellus.	Genesee Shale. { Tully Limestone. { Moscow Shale, { Encrinal Limestone. { Ludlowville Shale. Marcellus Shale.	Hamilton Group.	
				CORNIFEROUS.	Corniferous. Schoharie. Cauda-Galli.	{ Corniferous Limestone. { Onondaga Limestone. Schoharie Grit. Cauda-Galli Grit.	Corniferous Limestone.	*Devon & Eifel Limestones.*
				ORISKANY.	Oriskany.	Oriskany Sandstone.	Oriskany Sandstone.	
	Age of Algæ.	SILURIAN, OR AGE OF MOLLUSKS.	Upper Silurian.	HELDERBERG.	Helderberg.	{ Upper Pentamerus Limestone. { Encrinal Limestone. { Delthyris Shaly Limestone. { Lower Pentamerus Limestone. { Water-Lime Group.	Water Lime Group.	*Tilestone.* *U. Ludlow Bed.* *Aymestry Limestone.* *L. Ludlow Limestone.*
				SALINA.	Saliferous.	Onondaga Salt Group.	Onondaga Salt Group.	
				NIAGARA.	Niagara. Clinton. Medina.	{ Leclaire, Guelph and { Niagara Limestones. { Niagara Shale. Clinton Group. Medina Sandstone. Oneida Conglomerate.	Guelph Group. Niagara Limestone. Niagara Shale. Clinton Group.	{ *Wenlock Limestone.* *U. Llandovery.* *U. Caradoc Sandstone.* *Coniston Grit.* *Lower Llandovery.*
			Lower Silurian.	HUDSON.	Hudson. Utica.	Hudson River Shales. Utica Shales.	Cincinnati Group.	{ *L. Caradoc Sandstone.* { *and Bala Beds.*
				TRENTON.	Trenton. Chazy.	{ Trenton Limestone. { Black River Limestone. { Birdseye Limestone. Chazy Limestone.	Not exposed.	*Llandeilo Flags.*
				CALCIFEROUS.	Calciferous.	{ Quebec Group. { Calciferous Sandrock.	Not exposed.	*Tremadoc Group.*
				PRIMORDIAL.	Potsdam.	{ Potsdam Sandstone. { St. John's Group.		*Lingula Flags.*
EOZOIC.		EOZOIC.		EOZOIC.	Huronian. Laurentian.	Huronian System. Laurentian System.	Not exposed.	*Cambrian System ?* *"Fundamental Gneiss."*

agency of the carbon of plants. Still stronger evidence of the existence of life during the Laurentian ages is furnished by the immense masses of dolomitic limestone which are so conspicuous an element in the series. These limestones undoubtedly accumulated in the same manner as limestones have since done, through the agency of marine organisms, many of which secrete carbonate of lime to form their shells or skeletons. Among the corals there are also some groups which contain a large portion of magnesia, and many of the more recent limestones, such as are full of organic forms, and those to which an organic origin is universally ascribed, have a chemical composition similar to that of these ancient dolomites.

In addition to this circumstantial evidence, Dr. Dawson of Montreal, Dr. Carpenter, and Prof. Rupert Jones of England, and other accomplished microscopists are agreed in considering as of unmistakably organic structure some peculiar masses found in the limestones and serpentines of the Eozoic series. To this fossil the name of *Eozoon* has been given. and to the Canadian species the name of *Eozoon Canadense.* This organism has been referred to the group of *Foraminifera*, to which belong the "Lead Fossil" of the Galena limestone; the microscopic shells of chalk; the Nummulites of the limestone of the Pyramids, etc. It should be said, however, that the organic nature of *Eozoon* is denied by some geologists, Professors King and Rowney of Dublin leading the opposition to the view of Carpenter and Dawson.

The Eozoic rocks have been recognized in the Old World in England, in Sweden, in Bavaria, etc., there as here underlying the oldest and lowest of the fossiliferous rocks, and containing the *Eozoon.*

The upper division of the Eozoic rocks, the Huronian Group, is so named from the exposures it presents on the northern shores of Lake Huron. This group consists for the most part of dark, schistose rocks, hornblende slate, chlorite slate, clay slate, &c., and in the Eozoic area on the South shore of Lake Superior, back of Marquette—where both the Laurentian and the Huronian occur—the Huronian group holds the deposits of iron which have rendered this district so famous.

In Canada and the Adirondacks the Laurentian group carries the iron, and all the great beds of magnetic ore so extensively worked on the shores of Lake Champlain are contained in strata of Laurentian age. All these crystalline ores were at one time considered as erupted masses, which had been poured out like lava from the interior of the earth, but the evidence now before us clearly proves that they were once beds of stratified iron ore, like those of the Coal Measures associated with sandstones, limestones, shales, &c., and that their present structure and position is the result of the upheavals and metamorphosis to which all the members of the group have been subjected.

SILURIAN SYSTEM.

In Canada and in the state of New York where our older formations were first, and have been most fully, studied, the Eozoic rocks are bordered and partially overlaid by a series of sandstones, limestones, &c., which evidently accumulated in the ocean surrounding the ancient Laurentian continent and are made up from the materials derived from that continent by sub-aerial erosion. These strata form what is known as the *Silurian System*, consisting of the Potsdam sandstone, the Calciferous sand rock, the Trenton limestone, &c. They are, in places, filled with fossils, are for the most part undisturbed and unchanged; and lie in unbroken sheets which extend southward and westward until they pass under and are concealed by more recent rocks.

In some parts of New York and Vermont, at St. John's, New Brunswick, and on Newfoundland, strata have been discovered which underlie the Potsdam sandstone and yet overlie the Eozoic rocks. To some of these the name of Taconic System was given by Professor Emmons, and to portions of the same series, the name of St. John's group has been given by the Canadian geologists. These strata consist of slates containing many impressions of trilobites similar to those found in the oldest fossiliferous rocks of Europe.

POTSDAM SANDSTONE.

The first member of the Silurian System, the Potsdam sandstone, rests unconformably on the Eozoic rocks wherever the two are found in contact. This, as its name implies, is a sandstone, and is the first product of the invasion of the Eozoic continent by the ancient ocean, and the action of the shore waves upon its cliffs and surface. The Potsdam sandstone appears in a belt around the southern margin of the Eozoic area in Canada, the Adirondacks, and the region about Lake Superior, reaching as far westward as the Mississippi where it runs under and is concealed by the more recent deposits. Further west it appears in the Black Hills of Nebraska and in the canons of the Colorado, and in Texas; and it is also found in various parts of the Alleghany belt. It has also been reached in the deep borings made at Columbus,Ohio, Louisville, Kentucky, and St. Louis, Missouri, so that we have evidence that it stretches in an unbroken sheet beneath all the Valley of the Mississippi, and probably under a large part of the area occupied by modern rocks in the far-west.

The fossils of the Potsdam are generally not numerous. Produced, as this rock was, in most localities where found, by the action of shore waves on the land gradually invaded by the sea, the circumstances of its deposition were not favorable to the existence or preservation of many

mollusks, and from the fact that no land plants have left their traces here—in a consolidated beach where in later ages they were sure to be buried—we may fairly conclude that terrestrial vegetation was then exceedingly scanty if not wholly wanting. Seaweeds, sponges, mollusks and crustaceans existed in the sea which formed the Potsdam as we learn from their relics found in many localities. In New York its most characteristic fossils are two species of *Lingulepis* (*L. prima* and *L. antiqua.*)

On the upper Mississippi, where the Potsdam sandstone is represented by a finer and more calcareous sediment than at the East, it contains great numbers of trilobites, some of which are of considerable size. The group of sandstones and conglomerates interstratified with sheets of trap which contain metallic copper on Lake Superior have been usually considered as of the age of the Potsdam.

CALCIFEROUS SANDROCK.

Resting on the Potsdam sandstone, and forming by its outcrop a parallel belt of exposure, is a formation known among American geologists as the "Calciferous sandrock;" so named in New York from the fact that it there consists of a mixture of lime and sand. It is apparently composed of the sediments thrown down in the deeper waters, more remote from the shore than the Potsdam, and is the second product of the invasion of the ancient continent by the Silurian sea. This formation has also been reached in all the deep borings to which I have referred, and it evidently underlies the surface of an area nearly equal to that occupied by the Potsdam sandstone. The Calciferous strata are not everywhere composed of the same materials nor are so homogeneous as in New York. In Canada a great formation, called the Quebec group, is developed from the equivalents of the upper Calciferous beds, a group of strata exhibiting a variety of mineral characters and a large number of fossils not found at this horizon elsewhere.

In Missouri, too, the Calciferous strata form several massive beds of magnesian limestone which are described by Drs. Owen and Shumard and Prof. Swallow in their reports. This formation holds the lead of central and eastern Missouri. The most characteristic fossils of the calciferous strata are graptolites.

TRENTON GROUP.

On the Calciferous sandrock are found the rocks of the Trenton period consisting of the Trenton limestone with its associated underlying strata, the Chazy, Black River and Birdseye limestones. These form a calcareous mass usually from 300 to 600 feet in thickness, in places full of the remains of shells, corals, trilobites and crinoids; a formation which

undoubtedly resulted from the accumulation of organic matter at the bottom of the great Silurian ocean, when its waves rolled over most of the old Eozoic continent.

The Trenton group is exposed in New York, Canada, the region about Lake Superior and on the upper Mississippi—where one of its members, the Galena limestone, claims special notice as being the repository of all the lead of that region—in the Alleghany belt—where, like the Potsdam and Calciferous, it attains great thickness—in Tennessee, Kentucky, Illinois and Texas. It has also been recognized in the Rocky Mountains and in the Great Basin nearly as far west as the Sierra Nevada.

HUDSON GROUP.

Upon the Trenton formation rests the Hudson group, composed of the Hudson River and Utica slates. These rocks are mixed calcareous and argillaceous sediments, containing great numbers of fossils of which the most characteristic are those peculiar organisms known as graptolites. The surface occupied by the outcrops of the Hudson group forms a belt parallel with and more southerly than those of the older Silurian rocks, reaching from the Upper Mississippi about Galena, eastward, parallel with the south shore of Lake Superior, across the north end of Lake Huron and through western Canada and the eastern portion of New York. This formation is also brought to the surface at various points throughout the Alleghany belt.

To the inhabitants of Ohio the Hudson and Trenton groups are of special interest, inasmuch as they are the lowest rocks exposed within our territory, here known as the Blue limestone or Cincinnati group. The Cincinnati rocks are usually regarded as the equivalents of the Hudson and Utica shales, but they contain so large a number of Trenton fossils that they must be considered as in part, at least, the representatives of the Trenton limestone.

These older rocks are brought to the surface by an axis of upheaval reaching from Nashville to Lake Erie, parallel with the Alleghenies, but of more ancient date. They have been still further exposed by the cutting down of the valley of the Ohio about Cincinnati where nearly 800 feet of the series are exposed to view. In the boring of the Artesian well at Columbus about 1200 feet of blue calcareous rock was passed through which apparently represents the Trenton and Hudson rocks of New York.

This group of strata has further interest in the fact that it contains in various localities a large amount of bituminous matter, and constitutes the first and lowest oil horizon. The wells on the Upper Cumberland in

Kentucky, from which so much petroleum has flowed, were sunk in rocks of the Hudson age. On the shores of Lake Huron they are also highly charged with petroleum, and gas and oil escape from them.

The strata which have been briefly described on the preceding pages, form the *Lower Silurian Series.* In the succession, which has been noted, of first, mechanical (Potsdam) then mixed (Calciferous) and then organic (Trenton) sediments, we have an illustration of the sequence of deposits made in every submergence of the land. The earthy limestones of the Hudson period indicate a shallowing and retreating sea, an approach to land conditions and the completion of one circle of deposition.

ONEIDA CONGLOMERATE.

The rocks immediately superimposed upon those which have been enumerated are grouped together under the name of the *Upper Silurian Series.* They have been most carefully studied in New York where they have received the names of the Oneida conglomerate, Medina sandstone, the Clinton group, the Niagara group, the Salina group and the Lower Helderberg group. Of this series the Oneida conglomerate is the lowest member and is found in Central New York where it attains a thickness of 100 feet. Thence it extends in a narrow belt through southeastern New York, Pennsylvania and Virginia; attaining in the Alleghanies a thickness of 500 to 700 feet. This is the rock known in the Shawangunk mountains as the Shawangunk grit. It is composed of coarse materials, conglomerate and sandstone, and marks a period of land subsidence or water elevation, which apparently involved only a portion of the continent, and during which a long line of shore was thickly overspread with coarse materials torn from the coast by shore waves.

MEDINA SANDSTONE.

The Medina epoch was marked by the wide spread of mechanical sediments which graduate below into the Oneida where they are seen in contact. In central and western New York the Medina group has a thickness of 300 to 400 feet and is composed of sandstones and shales, of which the prevailing color is red, and the most characteristic fossils are a little wedge-shaped brachiopod (*Lingula cuneata*) and a sea-weed (*Arthrophycus Harlani*). Like most of our mechanical deposits, the Medina thins and becomes finer toward the west. It has been struck in borings for oil in northern Ohio, but does not show itself by any well-marked outcrop within the state.

CLINTON GROUP.

The Clinton group, like the Medina, is named from the locality where it is best exposed in New York. The formation consists of shales and limestones, mixed mechanical and organic sediments, which have naturally a wider reach than the purely mechanical materials of the Oneida and Medina. One of the most striking elements in the Clinton group is a peculiar bed of iron ore, called the "fossil ore," a granular red hematite which forms a stratum from two to ten feet in thickness, traceable from Dodge County, Wisconsin, eastward to the state of New York which it enters at Sodus Bay, thence southward through New York, Pennsylvania, Virginia and Tennessee into Georgia and Alabama. In the southern states it is well known as the "dye-stone ore." In Ohio the Clinton group is represented by a limestone from 15 to 50 feet in thickness, of which the outcrop follows the sinuous line of junction of the Lower and Upper Silurian in the region about Cincinnati. In Adams County, Prof. Orton has discovered the characteristic fossil iron ore as a component of the Clinton formation. Where most calcareous, the Clinton contains many fossils. Of these the most interesting are two graptolites, the last of the group which we find in ascending the geological column.

NIAGARA GROUP.

Above the Clinton lies a wider spread and more important formation which includes as its most conspicuous element a sheet of limestone, which, because it forms the shelf over which the cascade of Niagara pours, has received the name of Niagara limestone. The Niagara group is composed of nearly equal masses of limestone and shale, the latter becoming more calcareous toward the west. It forms a line of outcrop along the northern margin of the great Silurian basin parallel with those already described, and is a distinctly marked feature in the geology of most of the western states. This is the rock which underlies Chicago and that from which is derived what is known as the "Athens marble." From this region its outcrop sweeps along the northern margin of Lake Michigan, forms Drummond's Island, thence crosses Lake Huron and the Canadian peninsula to Niagara Falls. It is also traceable down the Alleghany belt to Tennessee, where it has a thickness not exceeding 100 feet. The Niagara group forms an important element in the geology of Ohio, and the characters which it presents here will be fully described in other portions of this volume.

SALINA GROUP.

The Salina is the formation from which the salt is obtained at Syracuse, and it has taken its name from this fact. It is more limited in its extent than those that have been described; its exposures being confined to western New York, portions of Canada, Michigan and Ohio. In New York the Salina—named by the New York geologists the Onondaga salt group—is composed of many alternations of colored marls and shales with some impure limestones containing gypsum. In northern Ohio it is the rock immediately overlying the Niagara and is that which contains the gypsum of Sandusky.* It is here only 30 to 40 feet in thickness and disappears by thinning out, within a few miles of this locality. The fossils of the Salina are very few, and it is evident that it was deposited under conditions not favorable to animal or vegetable life.† The most striking feature in the Salina is the salt it contains, and we have abundant evidence that the materials comprising it accumulated in shallow salt-water basins, where by solar evaporation the salt, gypsum and other constituents of sea water were precipitated with a considerable admixture of earthy matter. The era of the deposition of the Salina was one of continental elevation, accompanied by a retiring sea which left a series of shallow basins that became great evaporating pans. In Canada rock salt has been reached by boring in this formation and there is little doubt that similar masses, by their solution supply the constant flow of nearly saturated brine to the wells of Syracuse.

HELDERBERG GROUP.

The Helderberg group is so named from the fact that it forms a considerable portion of the Helderberg mountains south of Albany. It there attains a thickness of some two hundred feet, made up of several distinct strata, mostly earthy limestones. From this region it spreads southward along the Alleghanies and westward to the Mississippi. In the western states the Helderberg is apparently represented only by its lower or Waterlime subdivision which is somewhat thinner and more calcareous than at the east. It extends through western New York to the Niagara river and across the Canadian peninsula to Mackinaw and

* The gypsum of the Salina in Ohio is distinctly stratified; was evidently deposited with the associated strata as *gypsum* and was not formed by any change of limestone after deposition.

† The "Guelph" or "Galt" limestone of Canada, containing the large conchifer *Megalomus* and formerly considered a part of the Salina group in fact belongs to the Niagara group. *Megalomus* is not found in the Salina.

perhaps beyond. It may be identified by its ever present and characteristic fossil *Leperditia alta*. Less frequently but more certainly by *Eurypterus remipes*. The Waterlime is the surface rock over a large area in Ohio, and it will be frequently referred to, in subsequent portions of this report.

The Helderberg forms the summit of the upper division of the Silurian system, and completes a circle of sediments which corresponds in a remarkable way with that of the Lower Silurian. It also registers a similar round of changes in the physical geography of the continent. In comparing the two circles, the Oneida and Medina will be found to correspond to the Potsdam, the Clinton to the Calciferous, the Niagara to the Trenton, the Helderberg to the Hudson. The history recorded in each case is the same, viz., a submergence of such portions of the continental surface as now carry the sedimentary strata enumerated: in the progress of each submergence, the spread of shore materials, over all the surface covered by the advance of the sea; this sheet being followed first, by mixed mechanical and organic sediments, then by those almost purely calcareous deposits from the open ocean, and finally earthy limestones—mixed sediments—indicating a retreating, shallowing sea and a return to land conditions during which no deposition would be made on the surface, but which was the necessary starting point for a new circle of deposits. It will be remarked, however, that the submergence which has left its record in the Upper Silurian series was probably less extensive than that recorded in the Lower Silurian strata, as the spread of the Medina seems to have been less than that of the Potsdam and the reach of the Niagara less than that of the Trenton sea.

One interesting difference is observable in the character of the sediments which accumulated at the bottom of these Silurian oceans, viz., the limestones of the Trenton group are nearly pure carbonate of lime while those of the Niagara series—the Clinton, Niagara and Waterlime—are highly magnesian, in many instances typical dolomites. With the exception of two or three mollusks, the faunæ of the two Silurian seas were entirely different, and we must probably look to this difference for the distinctive chemical characters exhibited by the organic sediments of these seas. So far as we can judge of the drainage from the land and of the wash of the shores during the two periods, they would supply no more magnesia during the later than in the former. We might have expected indeed that the Lower Silurian limestones would contain more magnesia than those of the Upper Silurian, inasmuch as they were brought into close proximity to the dolomites of the Laurentian; while the Upper Silurian basin was underlaid, and as we know, in part, shored

by the Trenton limestones nearly free from magnesia. Such a shore was at least formed by some portion of the Cincinnati arch, which was raised between the Lower and Upper Silurian ages. We seem compelled, therefore, to ascribe the difference in the composition of the limestones to a vital, rather than to a chemical or physical cause. Prof. J. D. Dana has shown that the hard parts of some groups of marine invertebrates, the Millepores, for instance, contain a large percentage of magnesia, and the preponderance of these or similar organisms might produce a magnesian limestone.

I have already referred to the fact that the limestones of Calciferous age on the Mississippi are highly magnesian. The same is true of the Galena limestone of Trenton age, which in this respect contrasts strongly with its eastern representatives.

DEVONIAN SYSTEM.

The group of strata designated as Devonian have received their name from their prevalence in Devonshire, England. They form an important part of the geology of our country and of the world, occupying a large area of the surface, including one of our most valuable mineral staples as a characteristic ingredient (petroleum) and containing many strange forms of ancient life. In the Silurian strata we find a great number and variety of the lower orders of animals and abundant traces of marine plants, but in America no vertebrates and no land plants have up to the present time been discovered in them. In Europe relics of a terrestrial vegetation and the remains of fishes occur in the Upper Silurian. In this country fishes are first met with in the Devonian, but here, as in Europe, in large numbers of strange forms and attaining gigantic dimensions. Land plants are also found almost throughout the Devonian system in Canada, Maine, New York, West Virginia and Ohio, and the fossil flora obtained from these localities and described mainly by Prof. Dawson, rivals in the number of its species and the botanical grade of its genera the varied and beautiful flora of the Coal Measures.

Rocks of Devonian age underlie the surface over a large part of southwestern New York extending down through Pennsylvania and Virginia with less breadth of exposure but in greater force. The metamorphic rocks of New England are in part, as it is known, of Devonian age, while unchanged Devonian rocks are found in Maine, Nova Scotia, New Brunswick and many parts of eastern Canada. Here they are more calcareous than in our middle and eastern states, showing that they are in a less degree formed by the wash of the land. In the western states and western Canada the Devonian system is represented over a large territory

and has been recognized as far west as Utah and Nevada. In the Mississippi valley the Devonian strata are mostly calcareous and much thinner than in New York and Pennsylvania, showing plainly that here, as in eastern Canada, open sea prevailed during most of the Devonian age, and that the land from which only mechanical sediments could be derived was somewhat remote. Abundant evidence proves that it lay along the belt of the Blue Ridge and Green Mountains and in eastern New York and Canada. It should also be said that the Cincinnati arch formed a land surface over a considerable portion of its length, at least during the earlier, and probably throughout all the Devonian ages. This is shown by the fact that the Devonian strata thin out and vanish upon its flanks. No mechanical sediments were derived from this land, however, during the periods of deposition of the Upper Silurian and Devonian rocks, for the reason that it was exclusively a calcareous mass; though conglomerates composed of rolled limestone pebbles accumulated on its shore in the epochs both of the Clinton and the Corniferous. All the finer material which it furnished was either taken into solution or mingled, so as to be undistinguishable, with the organic sediments of the adjacent seas.

The strata which compose the Devonian system, as found and named in New York and grouped by Prof. Dana, are the following:

Periods.	Epochs.
Catskill	Catskill red sandstone.
Chemung	Chemung group. Portage group.
Hamilton	Genessee beds. Hamilton group. Marcellus group.
Corniferous	Upper Helderberg group. Schoharie grit. Cauda-Galli grit.
Oriskany	Oriskany sandstone.

It would be foreign to my purpose to attempt to give any detailed description of the various strata included in the foregoing list, and I shall confine myself in my notes upon them, to such points as seem to illustrate the vital and physical history of the continent.

ORISKANY SANDSTONE.

This formation, as its name implies, is a coarse mechanical sediment, called by the name of a New York locality. It occupies a limited area in central New York, but extends southward through Pennsylvania, Maryland and Virginia; like its prototype, the Oneida, greatly increasing in thickness in the Alleghany belt. In its south-eastern prolongation it is finer and more calcareous, and as at Cumberland, Maryland, contains a greater number and variety of fossils. In West Virginia it is a coarse sandstone attaining a thickness of several hundred feet. It thins out rapidly toward the west, but is recognizable at a great number of localities in Ohio, where it forms a sheet generally of saccharoidal sandstone, from 3 to 10 feet in thickness underlying the Corniferous. Further west it may be said not to exist, though some of its fossils have been recognized in Illinois.

SCHOHARIE GRIT.

The Schoharie grit is confined to New York and the Alleghany belt. It is a calcareous sandstone, from which the lime is dissolved by exposure, leaving it a rough porous rock, resembling the Oriskany in some of its phases, but containing different fossils. The Schoharie and Cauda-Galli grits only deserve mention in this connection from their homology with the Calciferous and Clinton groups. Like these they are mixed mechanical and organic sediments, beds of passage from coarse shore deposits to open sea organic sediments, and are similar links in the chain of events.

CORNIFEROUS LIMESTONE.

The most interesting member of the Devonian series in the west, is known as the Corniferous limestone; a massive calcareous rock, containing a very small percentage of earthy matter and abounding in fossils, especially corals, which in some places form what may be regarded as ancient coral reefs. It is called the Corniferous limestone from the balls of hornstone which are contained in it. It underlies a large part of western New York, and is there divided into two members, the Corniferous proper, and Onondaga limestones; a feature not noticable further west. The Corniferous limestone is found traversing the peninsula of western Canada reaching through Michigan to the Mississippi. In Ohio it forms two belts of outcrop on opposite sides of the Cincinnati arch, the northern end of which it formerly covered, but it thins out on its flanks

in southern Ohio and further south. In southern Kentucky it is very thin and only doubtfully present in Tennessee. West of the Cincinnati arch it passes southward through Indiana to the Ohio which it crosses at the falls. Southwesterly from this point its extent is unknown, as it is covered by more recent rocks. The average thickness of the Corniferous limestone in New York, Canada, Michigan and Ohio is about 100 feet. Analyses show that it contains about 20 per cent of magnesia, half as much as the Waterlime and Niagara, but much more than the Cincinnati group. The fossils of the Corniferous will be described in another part of this volume, and I will only say here in regard to them, that they are very numerous and of unusual interest; the most striking being the remains of huge ganoid fishes, similar in general character to those of the Old Red Sandstone of Scotland. Very unexpectedly the Corniferous has also yielded many fragments of land plants, among others, trunks of two tree ferns which were undoubtedly floated out to sea from some shore, probably that of the Cincinnati island which they had once adorned with their canopies of plume-like fronds.

The Corniferous limestone is an open sea deposit, the calcareous centre of a group of sediments, the product of a great submergence in the Devonian age, the counterpart in its general features, (though less extensive) to those which are found in the parallel deposits of the Upper and Lower Silurian series.

HAMILTON GROUP.

In New York a series of alternating shales and limestones overlying the Corniferous, form the Hamilton group. Like the Clinton, Niagara and Helderberg, it shows great variations in the purity of the water from which the sediments were deposited; variations doubtless dependent on oscillations in the level of the water surface, causing the deposits to vary in their position and character from what I have called *off shore* to *open sea*, and the reverse. In eastern New York the Hamilton is much more largely composed of mechanical materials, consisting of coarse sandstone with land plants in Schoharie County, fine blue sandstone, the famous Rondout flagging, on the Hudson. In Ohio and Michigan, the Hamilton group has lost its mechanical ingredients, has diminished greatly in thickness and is usually a soft blue limestone. The formation has little force in the valley of the Mississippi, yet it can be traced as far west as Iowa and Missouri.

PORTAGE AND CHEMUNG GROUPS.

In New York the shallowing of the Corniferous sea recorded in the Hamilton shales and sandstones, was followed by a period of oscillating sea level that kept a broad area in New York, Pennsylvania, Virginia and Ohio, in what we may term shore conditions, long enough for the accumulation of a greater thickness of mechanical sediments than occurs anywhere else in the series. These sediments have been named from localities in western New York, the Portage and Chemung groups. They consist of shales and sandstones which attain a thickness of at least 2000 feet. They are ripple-marked and sun-cracked, are thicker and coarser at the east, thinning out rapidly toward the west. We have, therefore, in this series of deposits, a record of another grand submergence of land surface, which was more or less broadly exposed at the close of the Hamilton. Fossils of the Chemung group have been found as far west as the Pahranagat district in Nevada, though no important strata of this age are known west of the great lakes. The western prolongation of the formation follows the general law and becomes limestone. The upper and coarser portions of the Portage and Chemung which have a thickness, in western New York and Pennsylvania, of from 1000 to 1500 feet, contain sandstones and conglomerates which resemble, and have been mistaken for, the Carboniferous conglomerate. What are called the Panama rocks in Chautauqua County, are portions of one of these layers. The error of considering this the Carboniferous conglomerate did much to create the confusion which prevailed so long in regard to the western equivalents of the Chemung rocks and the relations to them of the Ohio Waverly. In a reconnoissance made to connect the rocks of Ohio with those of New York and Pennsylvania, at one locality in Chautauqua County, the Panama conglomerate was found overlaid by 169 feet of shale containing an abundance of Chemung fossils. There can, therefore, be no doubt of its Devonian age. It is indeed one of many beds of sandstone—all of which are locally conglomerates—which are interstratified with the shales of the Chemung and upper Portage in western New York and Pennsylvania. The oil wells on Oil creek, if bored in the valley, begin near the surface of the Chemung, and the sandrocks in which the oil is found are those now referred to. In Ohio the Chemung and upper Portage rocks form the Lake shore as far west as the mouth of the Vermillion, where they thin out and disappear. To the Ohio portions of these strata the name of Erie shale has been given. The *black* shales of the lower Portage, which underlie the *green* sandstones and shales I have described,

united with the Genessee slate, are very persistent in their westward extension, and over a large area form a marked and interesting feature in the geological series. In Pennsylvania these are the "Cadent formation" of Rogers. In the Western states they have been generally known as the "Black slate" or "Black shale." This forms a belt of outcrop from the mouth of the Huron river to that of the Scioto, and here attains a thickness of 250 to 330 feet. It is continous southward into Kentucky and Tennessee, where it is exposed in a great number of localities on both sides of the Cincinnati anticlinal. In all this latter region it is comparatively thin, never exceeding 100 feet in thickness. This is the formation excavated in making the canal around the Ohio falls at Louisville. Thence its outcrop passes northwesterly through Indiana and Illinois. In Michigan it forms the lower part of Prof. Winchell's *Huron Group*. The two members of this group having nothing in common either in lithological characters or fossils, we have in Ohio separated them; giving the name *Erie* shale to the upper portion, retaining the name of Huron for the lower. The Huron shale is here somewhat interstratified with bands of more earthy shale, but exhibits a prevailing black color and contains nearly 10 per cent of combustible matter. The line of outcrop of the formation is everywhere marked by oil and gas springs, and in my judgment, this is the source of the petroleum obtained from the overlying shales and sandstones in western Pennsylvania. The disturbances which the rocks of that district have suffered, seem to have favored the disengagement of the oil which emanates from the bituminous shale by spontaneous distillation, while the sandstone strata have afforded convenient reservoirs for its reception. The immense productiveness of wells in the Pennsylvania oil region is probably due to the fact that the clay shales interstratified with, and overlying the sandstones, have formed an impervious cover to the reservoirs they afford. Hence the accumulation may have been going on for countless ages and the quantity be great because little or none has been permitted to escape. A similar geological and physical structure must prevail wherever productive oil wells, and especially fountain wells, are possible. The origin of this great sheet of carbonaceous matter which constitutes the Huron shale has been something of a puzzle to geologists. Without attempting to fully discuss the question, I venture to offer the suggestion that its carbon has been derived from sea weeds, and that it has been the product of a kind of sargasso sea. The impressions of fucoids are everywhere found on the layers of the shale and usually no other fossils are discoverable, but we have recently obtained from it the remains of fishes of great interest. Of these, the most remarkable is *Dinichthys* which will

be found described in another portion of this volume. The only molluscous fossils obtained from the Huron are, so far as I know, a *Lingula* and *Discina* distinct from *Lingula spatulata* and *Discina lodensis*, and the Portage fossils *Clymenia complanata*, *Chonetes speciosa* and *Orthoceras aciculum*. In many of the reports and papers on the geology of the West, the Huron shale has been called Hamilton or Marcellus. That it is not the Marcellus is easily demonstrable. The place of the Marcellus is immediately below the Hamilton, whereas the Huron is found in northern Ohio resting upon well marked Hamilton strata.

CATSKILL GROUP.

In Pennsylvania, another very interesting member of the Devonian system is found, one unknown at the west but which at the east attains a thickness of 400 feet and underlies an area of many hundred square miles. This consists of red sandstones and shales, in many places crowded with the remains of ganoid fishes of the same genera, and perhaps, in some instances of the same species, as those found in the Old Red Sandstone of Scotland. This group is known by the name of the Catskill formation, a name which it received when it was supposed to form a large part of the Catskill mountains. These are however now known to be composed mainly, perhaps exclusively, of older rocks. The Catskill formation is for the most part confined to Pennsylvania, scarcely reaching over the line into New York. It is probable, however, that it once reached far north of its present limits. I have specimens of unmistakable Catskill sandstone,—differing lithologically from the Pennsylvania Catskill, but containing the same fossils—from Gilboa, New York. In coming west from Tioga County, Pennsylvania, the Catskill appears to thin out entirely before reaching the Ohio line. The last traces of it may be seen on the Alleghany above Warren. From the nature of the materials composing the formation and its limited extent, it seems to have accumulated in a bay on the west side of the old Blue Ridge penin sula, just as the Triassic sandstone accumulated in similar bays, at a much later period, on the Atlantic margin of the continent.

I will close what I have to say in regard to the Devonian system, by simply calling attention again to the remarkable correspondenee which its circle of sediments exhibits to those of the Upper and Lower Silurian. From what has gone before, it will be seen, that in the Devonian series the circle is completed at the summit of the Hamilton; a new submergence resulting in the great thickness of shore deposits, which we find in the Portage and Chemung. With these latter groups, therefore, a

new circle begins, which includes, with them, the Waverly, the Carboniferous limestone, the Conglomerate and the Coal Measures. In this great circle we find many minor ones which indicate oscillations of sea level, and alternations of sea and shore conditions.

CARBONIFEROUS SYSTEM.

We have now reached in ascending the geological scale, the highest group of rocks found in Ohio, the group named Carboniferous, because it holds nearly all the beds of coal that have been worked in our own country and in Europe. From this circumstance the name would seem to be well chosen, but it is true that the Devonian shales, which have been already described, probably contain as large an amount of carbonaceous matter as is found in the Carboniferous Formation, yet so disseminated through the mineral constituents of the rock that it is not available to the same extent for economic purposes. It is also true that the rocks of more recent age in China, India and Western America include probably all the workable seams of coal there found, so that, if our geological nomenclature had been created by the Chinese or Californians, the Carboniferous system would have been fixed at a different horizon. In Europe and in America the conditions under which the Carboniferous rocks were deposited seem to have been nearly the same, as they show a remarkable correspondence both in their lithological characters and the fossils which they contain. There, as here, the great group of strata is divided into the Lower Carboniferous limestone, the Millstone grit, the Conglomerate and the Coal Measures. The Carboniferous or Mountain limestone marks a period of submergence, with the accumulation of a great thickness of nearly pure calcareous sediments over a great area; then the return to a terrestrial condition, with the deposit of a wide-spread sheet of gravel—subsequently consolidated into a conglomerate—on the underlying calcareous sea bottom; then along the shores of the new continent on low or marshy surfaces the accumulation by vegetable growth of beds of carbonaceous matter similar to the peat-bogs of the present day. With intervals of rest a gradual submergence of these areas took place, by which the first formed beds of coal were deeply buried under sand, clay and calcareous mud. These, when indurated, formed the sandstones, shales, limestones and fire-clays which are now interstratified with the beds of coal.

LOWER CARBONIFEROUS GROUP.

Of the series of epochs in the Carboniferous age, that of the Lower Carboniferous first claims our attention. At this time the land surface

of our continent was reduced by submergence to narrower limits than at any other time subsequent to the era of the Trenton sea of the Lower Silurian age. This is indicated by the fact that we find the calcareous sediments of the Carboniferous sea spread over perhaps a larger area than are those deposited in any other geological age. In the state of New York, in Canada, the region about Lake Superior, Wisconsin, Minnesota, etc., no Carboniferous strata are to be found; and though from some portion of this area—as the southern part of New York—they have been removed by surface erosion, yet we may fairly infer that the greater part of the territory indicated above, was dry land during all the Carboniferous age (as it has been through all succeeding ages). On the other hand all the area of the United States south of Lake Erie and Lake Michigan, except the Blue ridge and Cincinnati arch, from the Atlantic to the Pacific, was completely submerged during a part, at least, of this age.

In northern Pennsylvania and Ohio the Lower Carboniferous strata are not limestones but shales and sandstones, and it is evident that here we are upon the margin of the great Carboniferous sea, and in a region where the waters of that sea, probably fluctuating somewhat in level, were receiving the wash of a large continental surface. South of the southern line of Pennsylvania, and under all the coal basins of the West, and thence westward to the Rocky mountains, is a thick sheet of limestone which accumulated at the bottom of this sea. In Pennsylvania the Lower Carboniferous strata have been designated by Prof. Rogers by the names of the Umbral shales and Vespertine sandstones, the latter being the lower; while in Ohio the western extension of these same strata have long been known as the Waverly group. This latter formation, named by the former geological corps, has since that time been generally considered the equivalent of the Chemung rocks of New York, and therefore of Devonian age, but among the results of our first season's explorations in Ohio was the accumulation of abundant material for determining with certainty the Carboniferous character of the formation.

In passing southward from central Ohio and southern Pennsylvania, the Lower Carboniferous shales and sandstones are gradually succeeded by heavy beds of limestone which lap over and, to a certain degree, replace them, showing a progressive submergence of the continent by which the open sea conditions were carried further and further north; in the last portion of the Lower Carboniferous period reaching as far as central or northern Ohio. This is also proved by the fact that the limestone which forms the thin edge extending into Ohio represents only the upper or Chester division of the compound limestone mass.

In western Kentucky and Illinois, the Lower Carboniferous limestones

attain great thickness, and the mechanical sediments of the formation are but feebly represented; showing plainly that the land area from which they were derived lay on the east and north.

In the Lower Carboniferous strata the characteristic fossils are mollusks and crinoids, of which the fragments in some localities make up almost the entire mass. Fishes were also abundant in this age, and the teeth and spines of sharks were thickly scattered over the sea bottom.

CARBONIFEROUS CONGLOMERATE.

After a period which in some localities sufficed for the accumulation of a thousand feet of calcareous sediment, the bottom of the ocean was raised and from all of our territory east of the Mississippi, and a large area west of that stream the sea was entirely withdrawn and low, marshy surfaces were exposed, upon which the coal plants grew. Before the accumulation of the coal began, however, there was spread irregularly over much of this area a bed, frequently more than a hundred feet in thickness, of gravel and sand, which by consolidation has formed the Carboniferous Conglomerate. This Conglomerate in places contains the traces of marine organisms, shells and crinoids, but generally only the remains of land plants evidently drifted about and washed into some receptacle by the action of shore waves. The pebbles of the Conglomerate are sometimes three or four inches in diameter, are usually quartz, sometimes siliceous-slate. In certain localities in northern Ohio they include angular or slightly rounded fragments of chert containing Sub-carboniferous fossils, apparently derived from the Sub-carboniferous limestone, torn up by the forces which distributed the Conglomerate.

The method in which this mass of coarse mechanical material was spread over so great a surface will be considered in that part of the report where this formation is more fully described, but I may say in passing that I have not been able to imagine any agent by which this effect could be produced except that which during the Drift period spread so thick and broad a sheet of sand and gravel over the northern part of our continent, viz., *ice*.

COAL MEASURES.

At the period of the formation of the lowest bed of coal the level of the Carboniferous continent would seem to have been highest, as, when this stratum of bituminous matter had accumulated to the depth of a few feet, it was submerged by water that brought in shales and sandstones, and spread them in layers of many feet in thickness above it,

before the requisite conditions were reached for the formation of another stratum. And this would seem to have been the sequence of events throughout the formation of all the Coal Measures; for we find record of many repetitions of that circle of deposits; sandstone, shale and limestone, which has been so often referred to. The intervals of repose, when the surface of the land was nearly at a level with the sea, were marked by the accumulation of carbonaceous matter; and the thickness of each stratum measures the length of time during which this state of quiescence continued. The changes of level of which we here have the records, were *apparently* all in one direction, that of submergence; for during the epoch of the Coal Measures that which was the surface of the land, and at the sea level while the first stratum of coal was forming, was depressed until there had been deposited upon it a series of strata which measured in Ohio, before being eroded, fully 2000 feet in thickness, and included at least twelve workable seams of coal, with a great number of thinner ones. It should be remembered, however, that in oscillations of the coast level only the *submergences* are recorded by deposited sediments. During periods of emergence no deposits would be made, and there may have been many such in the immense interval during parts of which the Coal Measures were formed. In the region west of the Mississippi, however, a different history is recorded in the Carboniferous strata. There the submergence of the continent during the Lower Carboniferous epoch was not so general, and the Lower Carboniferous limestone was deposited in but few localities. At the time, however, when the central and southern portions of the valley of the Mississippi were brought to the surface and the accumulation of coal began, the depression of the western portions of the continent was greater than before, and it continued all through the Coal Measure ages. Proofs of this we find in the facts that the mechanical sediments which accompany the coal, and the coal itself, gradually lose their importance in the series as we go westward; while the limestones interstratified with the coal seams,—and which, east of the Mississippi, are comparatively thin—thicken up toward the west until finally they supplant completely the mechanical sediments, and an unbroken series of limestones constitutes the entire mass of the Carboniferous series. During all this interval the greater part of New England and New York, the whole of Canada, and the country bordering Lake Superior within our own territory, was above the sea level and failed to receive any contribution from the causes then in operation and which were fraught with so great consequences to the present inhabitants of our country.

In the region around the mouth of the St. Lawrence, part of which is

now represented by Nova Scotia, a series of changes were taking place similar to those which marked the progress of the Carboniferous period in the valley of the Mississippi, and even on a grander scale. For, if we may believe the very trustworthy geologists who have studied the structure of that region, the submergence of a local basin permitted the accumulation of more than 14,000 feet of Carboniferous strata, among which are to be enumerated some of the thickest and most valuable beds of coal known to exist.

When the period had been reached in our geological history that witnessed the formation of the highest of our beds of coal, a most important change took place in the topography of the continent. At this time the Alleghany Mountain System was elevated, and an area including most of the states of our Union was raised above the ocean, never, to the present time, to be submerged. In later geological ages stupendous changes have been going on in the western half of the continent, but here a condition of almost constant geological quiet has prevailed.

The beds of coal which form so noticeable a feature in the strata of the Carboniferous formation are in our country spread over an area of vast extent. This area is now divided into several districts which are denominated coal *basins*, from the fact that the rocks which underlie them form curved sheets, of a basin, or trough-like shape. Of these the most important one, called the Alleghany Coal-field, reaches from the southern margin of New York to the interior of Alabama, occupying a broad and somewhat irregular belt on the west side of the Alleghany mountains. Its length is over 700 miles, its average breadth something like 80, and its area about 60,000 square miles. The anthracite coal basins of Pennsylvania, which lie between the ridges of the Alleghanies were once unquestionably a part of the great Alleghany Coal-field, but have since been isolated by the upheaval and erosion of the mountain ridges which separate them. By the disturbances which affected this portion of the coal basin all the rocks were more or less metamorphosed and most of the volatile ingredients of the coal driven off, leaving it in the condition of anthracite.

In Rhode Island there is another coal field of limited extent where the disturbance was greater and the metamorphosis more complete. Here much of the coal has been converted into graphite, so that it may be called a graphitic anthracite. From this point the coal becomes more and more bituminous towards the West, viz., normal anthracite in eastern Pennsylvania, semi-bituminous coal in Central Pennsylvania,—as at Blossburgh, Cresson, Broadtop and Frostburg,—normal bituminous coal at Pittsburgh and in Ohio.

West of the Alleghany Coal-field lies the Cincinnati anticlinal, composed of the infra-carboniferous rocks, and raised long before the Carboniferous era. All the facts in my possession lead me to believe, that at least in Ohio, this barrier always separated the Alleghany Coal-field from that of Illinois. This latter coal basin occupies a large part of the state of Illinois, the south-western portion of Indiana, and the western part of Kentucky, having an area nearly equal to that of the Alleghany Coal-basin. The western margin of the Illinois Coal field is formed by the immediate valley of the Mississippi which has been excavated through it, and separates it from a large coal area lying in the states of Iowa, Missouri, Kansas, Arkansas and Texas. The limits of this last mentioned coal-field are not yet actually known, for part of it lies in a country but imperfectly explored, and its western margin is overlaid by more recent rocks which obscure the extent of the coal seams.

In addition to the surfaces that have been enumerated, occupied by the productive Coal Measures, a coal basin of limited extent lies in the interior of the state of Michigan. The aggregate extent of our Carboniferous Coal measures is at least 150,000 square miles ; ten times that possessed by any other nation.

The most characteristic fossils of the Coal measures are plants, of which probably a thousand species have already been described. These are for the most part ferns, but with these are several genera of trees peculiar to the coal flora, and having a close affinity with the *Lycopodiaceae*,—the club mosses of our present flora. On the higher lands of the Carboniferous continent grew forests of coniferous trees allied to the *Araucaria* or Norfolk Island pine. The seas of this period abounded in mollusks, fishes, corals and crinoids of which the remains constitute a great group of characteristic genera and species. This era in the life history of the globe was also distinguished by the introduction of a higher order of vertebrates than any before existing, the amphibians—to which our frogs, salmanders, etc., belong—of which several genera and species will be found described by Prof. Cope in another part of this report. The Coal Measures of Europe exhibit a remarkable similarity to those of our own country both as regards the nature and arrangement of the strata which compose them and the fossils they contain. Of the plants and mollusks of the Carboniferous strata nearly one half the species known are common to both sides of the Atlantic, and there are some facts which indicate that the coal strata of Europe and America were not only deposited at a corresponding time in the order of geological sequence, but that they were formed simultaneously. This conclusion is, however, not to be accepted without further evidence, as the progress of geological knowledge tends to the

belief that the fauna and flora which characterize each of the different ages in geological history have spread by migration, and consequently that in widely separated localities they may almost be accepted as proof of a want of synchronism. It is certain that their migrations from one to the other of these localities, or from some common center of radiation, could only have been accomplished in long intervals of time. It should be remembered, however, that the time occupied in the deposition of any of the great geological formations such as the Coal Measures, is to us simply incomprehensible and infinite, and the migration to which I have alluded may have been made in so small a fraction of this time that during the greater part of their deposition these formations may have been absolutely synchronous. All that geologists claim, however, is that the order of sequence is the same in all countries. The epoch or period of deposition of each formation holds a fixed place in the chain of events; but whether the corresponding links in this chain are of the same precise date is a question which is only to be settled by future investigations. Fortunately it in nowise affects the integrity of the geological records.

I have now reviewed briefly the relations of all the geological formations found in Ohio, except the Drift. As will be seen by referring to the chart which accompanies this chapter, all the upper portion of the geological column, with the exception of its extreme summit, is wanting here. The most recent of our rocky strata belong to the upper portion of the Carboniferous system; while between that and the Quaternary all is a blank. The Secondary and Tertiary ages have passed, leaving a voluminous record elsewhere, but here only truncated hills and eroded valleys to mark their lapse. Even the highest members of the Carboniferous series, which were doubtless once deposited within our limits, exist here no longer, for they have been worn away and their comminuted fragments carried off by the Ohio have gone to make up the more recent strata deposited on the shores of the Gulf. By going to the center of the Alleghany coal field, which lies in West Virginia, we can see in place a portion at least of the strata which have been removed from our surface. Between 1000 and 2000 feet of the Upper Coal Measures remain there which are not now represented in Ohio. But even these, so far as we know, include no rocks of later date than the Carboniferous age.

The reason why the upper portion of the geological column is wanting in our state will be readily understood by those who have read the preceding portion of this chapter. It is simply this. At or near the close ot the period of the Coal Measures, nearly all that portion of our continent which lies between the Atlantic and the Mississippi was raised above the sea, and from that time to the present only the margins of this area

have been submerged so as to receive any deposits during the later geological ages. The elevatory movement which carried up much of the eastern half of our continent was accompanied by, or culminated in, the upheaval of the Alleghany mountains. For it is well known to geologists that all the stupendous changes which resulted in the formation of this great mountain system, took place subsequent to the Carboniferous and anterior to the Triassic age. By the action of the forces that were in operation at that time not only all the folds of the Alleghanies were formed but the rocks which underlie our State were warped and corrugated to such a degree as to completely change both the surface and substructure of that portion which lies east of the great Cincinnati anticlinal.

The effects produced by the forces which elevated the Alleghanies are so stupendous and impressive that they have, very naturally, been ascribed to some extraordinary and overwhelming cataclysm, but we shall probably find that these as well as other great changes which are recorded in the earth's crust are the product of slowly acting, though resistless forces.

> "Though the mills of God grind slowly
> Yet they grind exceeding small."

This is scarcely the place to discuss the phenomena of mountain formation, but I may say in passing that the proof is accumulating that the recurring elevations and depressions of the continent which are described on the preceding pages of this chapter, as well as the upheavals of mountain chains, can be shown to be the effects of forces that have continued their action through countless ages.

THE MISSING CHAPTERS IN OUR GEOLOGICAL HISTORY.

I might perhaps with propriety pass from the review which I have given of the relations of the elements composing the rocky substructure of Ohio directly to the consideration of the phenomena of the Drift, and thus omit all reference to such portions of the geological history of our continent as have left no record within our state limits. I have thought, however, that this sketch of the growth of the continent of which Ohio forms part, would be more complete and intelligible if it contained some allusion to the missing links in our history, and that the two portions of our record might in this way be so connected that their relations would be clearly comprehended. With this view I propose to notice here very briefly some of the changes which were taking place in other portions

of our continent in the long interval between the Carboniferous and the Quaternary ages.

Permian period. In Russia, a group of rocks overlying the Carboniferous, having great geographical extent and considerable thickness, from their development in the kingdom of Perm have been designated as the Permian System. No evidence of the existence of this group of strata had been met with in this country until about ten years since. Then, Prof. Swallow of Missouri, and Mr. Meek, now the palaeontologist of the Ohio Survey, discovered in Kansas strata overlying the Coal Measures which contain some of the characteristic fossils of the Permian. These were, however, mingled with Carboniferous species and the beds which contain them are conformable with the Coal Measures beneath; so that it is impossible to draw there any distinct line between the Permian and Carboniferons systems. The "Permian" fossils of Kansas were found by myself in similar relationship near Santa Fe, New Mexico, and they will probably be obtained in the extreme upper members of the Carboniferous series wherever these are reached. None of the Coal Measures of Ohio are high enough to contain them, but it is not unlikely that they will be discovered in the uppermost strata in the axis of the trough of the Alleghany coal field in West Virginia.

Triassic period. Passing from the Carboniferous and Permian we leave behind us all that great group of formations called by geologists the Palaeozoic, and enter upon a new series to which the term Mesozoic has been applied. This series comprises the Triassic, Jurassic and Cretaceous systems. As has been before remarked, none of these groups are found in Ohio nor in the area lying between the Alleghanies and the Mississippi north of Tennessee. On the Atlantic and Gulf coasts, however, and over an immense area in the far west, these more recent deposits form the surface rocks. The first and lowest of the Mesozoic groups, the Trias, is represented on the Atlantic coast of North America by the brown sandstone of the Connecticut river valley and New Jersey; also by the rocks which compose the small coal basins in the vicinity of Richmond, Va., and in North Carolina. West of the Mississippi river the Triassic rocks are much more largely developed. In the central part of the continent they lie conformably upon the Permian or Carboniferous, and occupy a broad belt extending through the plains from Nebraska to Texas underlying most of the Llano Estacado and a large area in New Mexico and southern Utah. In California, Nevada and Sonora, the Triassic rocks consist of shales and limestones for the most part highly metamorphosed, and with the Jurassic slates, from which they can hardly

be distinguished, holding the quartz veins which carry the gold. The Triassic rocks of the middle portion of the continent attain a thickness of 2000 to 3000 feet, covering an area of many thousand square miles and exhibiting the same general character throughout, viz: they are red sandstones, shales and variagated marls, with beds of gypsum and rock salt. They seem to me to have been deposited during the shallowing and retreat of the great Carboniferous sea when it gave place to a wide spread continental surface. We know that the period of their deposition was immediately preceded by a submergence that was almost universal, west of the Mississippi, and they were succeeded by land conditions scarcely less general. Beside this, their peculiar composition, as it seems to me, is susceptible of but one explanation. These red sandstones, generally fine and calcareous, cross-stratified and ripple marked; green, blue, yellow and red marls, impregnated with salt, holding sheets of gypsum and peculiarly barren of fossils could hardly have been deposited elsewhere than in broad, shallow basins, where the sea water was evaporated till it formed a solution too strong for animal or plant life, and where the sulphate of lime and the chlorides of sodium, calcium and magnesium were ultimately precipitated in a solid form. In short, we had at this period of the world's history a recurrence on a much grander scale of the conditions which resulted in the deposition of the Salina group in the Upper Silurian age. The Triassic rocks are generally very barren of fossils. To this rule there are, however, some marked exceptions. In Nevada, the Trias at certain localities is highly fossiliferous. It is there an impure limestone from which a large number of species of *Ammonites* and other shells have been obtained. The Triassic formation has also furnished an interesting series of fossil plants obtained from the coal strata of Virginia and North Carolina, by Profs. Rogers and Emmons, from Abiquiu, New Mexico, by myself, and at Los Bronces, Sonora, by Mr. Remond. This flora is composed of *cycads*, *conifers* and *ferns* and all of the genera and several of the species are such as occur in the Trias of Europe.

The strange series of tracks found in the sandstones of the Connecticut valley—generally known as bird tracks but probably for the most part reptilian—show that similar faunas as well as floras existed on both sides of the Atlantic during the Triassic age.

Jurassic system. In the progress of the formation of the great continent which was mainly produced by the emergence of the Triassic sediments from the Carboniferous sea, along certain shores of the newly formed land a series of strata were deposited more recent than the Triassic and

which correspond in position and fossil remains with the Jurassic of the old world. The rocks of this group, in Europe, are the depositories of some of the most remarkable forms of ancient life. Of these, the most interesting are the gigantic reptiles which in this and the succeeding period inhabited the sea and the land. They were carnivorous and herbivorous, walking, swimming and flying, reigned as monarchs of the animal kingdom at the time, and the era in which they lived has been appropriately designated the Reptilian age.

In the Jurassic rocks of our own country few remains of these great reptiles have as yet been met with, but we have evidence that they abounded in the other Mesozoic periods—the Triassic, before and Cretaceous, after—so that we may conclude that their absence is simply an imperfection of the geological record. It should also be said that the limited districts occupied by Jurassic rocks in America, lying as they do, in the far west, have been but imperfectly examined and more thorough exploration may yet bring to light as rich a fauna there as that contained by the Jurassic of Europe. So far as yet known our Jurassic strata are confined to Alaska, California, Colorado, and Wyoming.

Cretaceous system. This group of strata takes its name from the Chalk which in England constitutes a conspicuous element in the series to which it belongs. Chalk is, however, really a limestone and is composed almost entirely of microscopic shells. It is a deep sea deposit and nearly identical in composition with the ooze drawn up from great depth in the soundings made in our present seas. In North America we have scarcely any true chalk, but the Cretaceous series covers probably a greater breadth of surface than any other. It forms a narrow belt back from the shore of the Atlantic and Gulf in our southern states, and except where broken through by the upheaval of mountain chains or removed by erosion, it may be said to underlie the surface of a much greater belt reaching from Mexico through Texas northward far into the British possessions; its eastern margin half way between the Rocky mountains and the Mississippi; its western on the same parallel being formed by the Wasatch mountains. In addition to this the Cretaceous rocks occupy a large part of western Mexico, California, Washington and Oregon territory and Vancouver's island. Here as in the old world the Cretaceous strata contain great numbers of interesting fossils of which the chambered shells, *Ammonites*, *Baculites*, &c., form a conspicuous feature. Here are also found numerous remains of the great reptiles so characteristic of the Mesozoic rocks of Europe, with many gigantic species peculiar to America; and we may say that in this country the Cretaceous was the culminating period of the Reptilian age.

It should also be mentioned that in North America the Cretaceous was a great coal making period, as rocks of this age in the far west contain at various points important beds of lignite some of which are from 30 to 50 feet in thickness. The coals of Vancouver's island, Bellingham bay, Mt. Diablo, those of New Mexico and Arizona, as well as some of the most valuable beds in Utah, Colorado and Wyoming, are of Cretaceous age. These with some Tertiary lignites comprise all the so called coals of the far west.

The topographical changes which took place on our continent during the Cretaceous period were very striking. We have seen that when the great Carboniferous sea was withdrawn it left exposed in the west extensive mud flats and salt pans where the peculiar series of deposits belonging to the Triassic accumulated. Ultimately all this great area became dry land and was covered with a luxuriant forest growth of very different botanical character from the cycadaceous flora which preceded it; since it was composed of the highest order of plants—the angiosperms—such as constitute most of our present flora. In these forests of the Cretaceous were many genera of trees which have continued to exist to the present day, such as oaks, magnolias, willows, tulip trees, &c. After the lapse of ages—how many we know not—our continent began again to sink, and that portion west of the Mississippi was gradually submerged until the sea rolled its waves from the Gulf of Mexico to the Rocky mountains on the west, to the Arctic ocean on the north. A consequence of this submergence was the formation of an unbroken sheet of beach sand over all the depressed area. This sand, the direct *debris* of the land, everywhere included relics of the land vegetation; for wherever we now examine it we find it consolidated to a sandstone containing the impression of leaves and the trunks of trees. These have been collected from many and widely separated localities and represent fully 100 species of arborescent plants; showing that the forest growth of the Cretaceous period was as varied and luxuriant as that which now covers any portion of our territory.

On the mechanical sediment to which I have referred were deposited the organic sediments of the open ocean. These are now limestones, in many places full of marine organisms, among which are to be found all the strange cephalopods that characterized the fauna of the Cretaceous period.

Although copying so closely the Cretaceous series of Europe, our rocks represent only the middle and upper portions of the Cretaceous System; the Wealden and Neocomian, the oldest European members of the Cretaceous not having been as yet clearly identified anywhere in America.

This proves that the submergence I have described began only when a considerable part of the Cretaceous age had passed.

Before closing this brief notice of the Cretaceous system I should perhaps refer to the somewhat widely circulated report that the recent deep sea dredging expeditions had found the Cretaceous fauna still existing in the before unexplored depths of the ocean. This misstatement doubtless arose from the fact that a few genera of crinoids, two or three in all, have been obtained in recent deep sea dredgings, which have continued to exist since the Cretaceous age, but many more Cretaceous genera of animals and plants were before known to be now living, and some of our genera date back very much farther than that. All these are, however, mere relics and fragments of the fauna and flora which characterized the long past geological ages. Certainly the Cretaceous age—when only a few insigificant mammals lived; when the monarchs of the animal world were reptiles in infinite variety and attaining colossal size, when the land was clothed with different vegetation and the sea thronged with huge and curious chambered shells—has passed, never to return.

Tertiary system. When the Cretaceous sea had prevailed so long over those portions of our continent which were sunk beneath it that more than 2000 feet of calcareous sediment had accumulated at its bottom, the land began again to rise and the sea gradually retreated to the position it now holds. During this retreat, or the oscillations of level which accompanied it, a series of strata were deposited which have been denominated the "Tertiary" or third great geological sub-division. In this group are embraced all the strata that contain any species represented in the existing fauna and flora of the globe, and they are divided into three subordinate groups, the Eocene, Miocene and Pliocene, the latter the most recent. These Tertiary rocks form the Atlantic and Gulf coasts and reach a long distance up the valley of the Mississippi. In the far west the Miocene and Pliocene are largely developed while the Eocene is only doubtfully present. In the Great Basin and the region of the plains there are wide areas of Tertiary strata which occupy the beds of ancient fresh water lakes. They consist for the most part, of marls and impure limestones containing impressions of plants, fresh water shells, the remains of fishes and reptiles and also the bones of mammals. Of the latter a large number of species have been described belonging to the genera *Elephas*, *Rhinoceros*, etc., etc., with many strange extinct forms; a group closely allied to the mammalian fauna of the old world Tertiaries and such as from their number and magnitude have given to this period in the life history of the globe the name of the Age of Mammals.

The flora of our fresh water Tertiary strata is very rich and of great interest. More than 100 species—mostly arborescent plants—have been brought to light in the Miocene beds of the Upper Missouri, while perhaps an equal number has been collected from the deposits of similar age west of the Rocky mountains. The flora of the Miocene of the northwest indicates a climate much like that of our southern states, since it includes fan palms and yet contains a number of plants which are now growing over the greater part of our country, such as our two hazels,—*Corylus Americana* and *C. rostrata*—the common fern *Onoclea sensibilis*, etc.

An additional interest has been given to our Miocene vegetation by the discovery that it extended as far north as the Arctic sea. From facts which cannot with propriety be cited here, it is evident that in the Miocene epoch a flora botanically similar to that which now prevails over the temperate zone of our continent covered all its northern portion and reached to China and Japan on the one hand, to Greenland, Iceland, the Hebrides and the continent of Europe on the other, and that a temperate climate not colder than that of Ohio prevailed over the northern hemisphere so far as explorations have yet been made. The contrast which this condition of things presents to that recorded in the next chapter of our geological history is very striking.

QUATERNARY SYSTEM.

The deposits of the Drift period form part of the geological series represented in Ohio and possess peculiar interest from the part they have played in modifying the surface; hence they will be described more at length in other portions of our report. Here I shall only briefly refer to them in order to complete the sketch which fills the preceding pages of this chapter.

The period immediately following the Tertiary age in geological history, but separated from it by we know not how many thousands of years, presents us with a complete change in the physical condition not only of our own continent, but apparently of the whole northern hemisphere; a change not exceeded by that which takes place upon our surface in the alternations of season from midsummer to mid-winter. We have abundant evidence that during what is called the Drift period the climate of our continent had changed from the all pervading warmth of the Tertiary to an all pervading arctic cold. While in the former age the climate of our southern states was carried to Greenland, in the latter the present climate of Greenland was brought as far south as the Ohio. The continent of Greenland is now nearly buried under snow and ice, and on a large

part of the coast, access to the interior is debarred by ice precipices formed by the great glaciers which flow from the interior to the sea. Precisely such must have been the condition of much of the North American continent during the glacial period, for we find evidence that glaciers covered the greater part of the surface down to the the latitude of 38 or 40 degrees. Throughout all the northern half of our national domain the rock surfaces, wherever the material has resisted more recent decomposition, are planed, grooved and striated in a way that no other agent than ice marks rocks. Similar phemomena are met with throughout much of the northern hemisphere in the old world, and the proof is conclusive that this ice period was common to both, and that then glaciers, or great masses of moving ice, filled all our valleys, covered most of our plains with a thickness of many hundreds, perhaps thousands of feet and rolled over our highest hills. By this agency the character of the surface was greatly modified, its asperities smoothed off and many of its basins and valleys excavated.

Upon the polished surface left by the ice we find laid down a series of beds known as the Drift deposits. These are clays, sands, gravel and bowlders which have all been transported greater or less distances from their place of origin and have for that reason received the name they bear. When carefully examined the Drift deposits are found to present a constant order of arrangement which is briefly as follows: The glacial surface is generally covered first by gravel and bowlders or an unstratified clay thickly studded with small fragments of rock found in place at no very distant points. Mingled with these are generally a few, sometimes many pebbles and boulders of crystalline rocks, such as are only found north of the great lakes. These are generally rounded, ground and striated. In Ohio they are usually small and few; farther north larger and more abundant. This sheet of clay and boulders I have termed the *Glacial Drift* because it seems to be the direct product of glacial action. Second; upon the Glacial Drift blending with and shading into it we have, not everywhere, but in many localities a fine stratified clay which has been designated as the *Erie clay* by Sir William Logan. Like the underlying boulder clay the Erie clay is blue below and where protected from the action of the air, yellow above where the iron it contains is converted by exposure from the protoxide into sesquioxide. The Erie clay has plainly been deposited from suspension in water and doubtless accumulated at the bottom of the water basins which occupied the place of the retreating glaciers. Third; upon the clays I have described there is found over a wide area in Ohio and other western states a layer of carbonaceous matter with logs and stumps, sometimes upright trees. This is apparently an ancient soil which sustained a growth of vegetation that covered a large

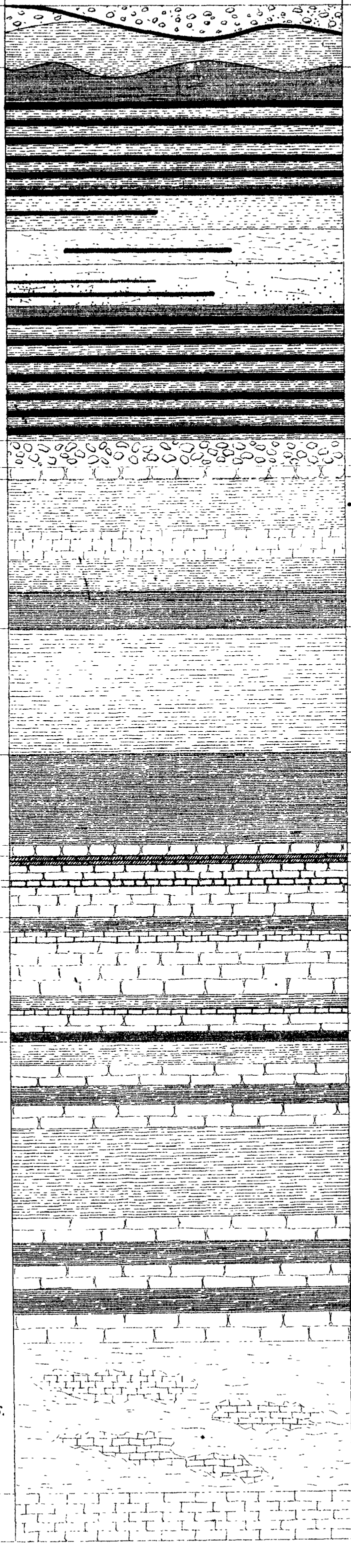
part of the area abandoned by the ice. This carbonaceous layer I have termed the *Forest bed.* The remains of the elephant, mastodon and giant beaver are found in and above this deposit, but not below it. Fourth; overlying the Forest bed we find a series of stratified deposits, gravel, sand and clay, sometimes of great thickness, evidently the product of a submergence by which the Forest bed was deeply buried under a mass of transported material. Fifth; scattered over the surface of the underlying Drift deposits, and forming the last and topmost member of the series, are numerous boulders, often of great size. These are usually of crystalline rock, granite, greenstone, silicious slate, etc., rocks found in place nowhere nearer than the Canadian highlands and the Eozoic district on the south shore of Lake Superior. With these boulders have been, found many masses of native copper, obviously derived from the Lake Superior copper region. The boulders I have described are frequently seen resting on fine, stratified clays which would have been broken up and carried away by currents of water or glaciers,—the agents which have often been credited with the transport of the boulders,—they must have, therefore, been floated to and dropped upon their present resting places. In my judgment no other agent than floating ice could have accomplished their transport in the manner in which it has been done. Hence, I have considered them as the result of iceberg action, and have termed them and the northern gravel with which they are associated, the *Iceberg Drift.*

With the distribution of the erratics the history of the Drift proper closes. In reviewing it we see; first, the Glacial period, in which glaciers reached as far south as Cincinnati, planing, grinding down and smoothing all rock surfaces and excavating the basins of our great lakes; second, the retreat of the glaciers, leaving clay and boulders spread over the glaciated surface as they abandoned it; third, a great inland sea of fresh water filling the basins, before occupied by ice. (The northern shore of this great lake was formed by the ice wall of the glacier foot while its bottom was covered with such portion of the mud ground up by the glacier as was taken into suspension. This mud is now the Erie clay.) fourth, the spread of a forest growth over a large part of Ohio, Indiana, Illinois, etc., and the formation of a soil, the Forest bed; fifth, an elevation of the water level to a point 500 feet above the present surface of Lake Erie and the formation of icebergs by the detachment of great masses of ice from the glacier foot, which now rested upon the hills of Lake Superior and Canada, composed of crystalline rock. These icebergs held in their grasp—as do those which float in the Atlantic at the present day—great quantities of gravel and boulders which were sown broad cast over the then submerged rim of the basin of the lakes. At a later period,

by continental elevation or the removal of barriers to drainage, the water level was gradually depressed until the inland sea was reduced to the comparative insignificance of our "great lakes."

The descent of the water level would seem to have been paroxysmal, or at least, if gradual, it was interrupted by long periods of rest. During these periods the waves cut deeply into elevated shores and washed up ridges or raised beaches wherever the shore was more nearly level and composed ot soft materials. These old shore lines are now distinctly marked by terraces and ridges which will be found fully described in another part of this report.

VERTICAL SECTION OF THE ROCKS OF OHIO.



SYSTEMS	GROUPS.	STRATA.	AV. THICKNESS. FEET.
QUATERNARY.	Drift.	Delta Sand. Forest Bed. Erie Clay.	200.
CARBONIFEROUS.	Coal Measures.	Upper Coal Measures. Barren Measures. Lower Coal Measures.	1200.
	Conglomerate.	Conglomerate.	100.
	Lower Carb. Limestone.	Chester Limestone.	20.
	Waverly Group.	Cuyahoga Shale. Berea Grit. Bedford Shale. Cleveland Shale.	500.
DEVONIAN.	Erie.	Erie Shale.	400.
	Huron.	Huron Shale.	300
	Hamilton.	Sandusky Limestone.	20.
	Corniferous.	Columbus Limestone.	100.
	Oriskany.	Oriskany Sandstone.	10.
UPPER SILURIAN.	Helderberg.	Water Lime.	100.
	Salina.	Salina Shale.	40.
	Niagara.	Hillsboro Sandstone. 30; Niagara Limestone 180; Niagara Shales. 60; Dayton Stone. 5	275.
	Clinton.		50
	Medina.		20.
LOWER SILURIAN.	Cincinnati Group.	Lebanon Beds. Eden Shales. Mt Pleasant Beds.	1000.
	Calciferous.	Calciferous Sandrock.	475.
	Potsdam.	Potsdam Sandstone.	300.

Strobridge & Co Lith. Cin.

CHAPTER IV.

THE GEOLOGICAL STRUCTURE OF OHIO.

SECTION I.—THE PHYSICAL STRUCTURE AND RELATIONS OF THE STRATA.

The general relations which the geology of Ohio sustains to that of adjacent states and the continent at large, are given in the preceding chapter. The local phenomena exhibited by the different formations which come to the surface within our territory present themselves next in order for consideration; but before entering on any detailed description of the strata and fossils which characterize the different groups included in our geological series, I have thought that a few words should be said in regard to the general physical structure and arrangement of the rocks which underlie the state.

To the casual observer, the physical sub-structure of Ohio may seem to be, like its surface, simple and almost monotonous, but upon more careful examination it will be found to be locally diversified, both as regards the number, character and thickness of the strata, and the positions which they occupy relative to each other and to the horizon.

There are in Ohio no such conspicuous arches and dislocations of the strata as are found in the neighboring states of Pennsylvania, New York and Virginia, but the rocks are no where absolutely horizontal, and when traced over considerable intervals, they are found to exhibit a series of waves or folds, of which the magnitude is masked by the broad and general erosion that has affected the surface, and by the deep and continuous sheets of superficial materials which so generally cover and conceal the underlying rocks.

The most considerable fold which has disturbed the strata of Ohio is that of the Cincinnati anticlinal. This forms so striking and interesting a feature in our geology, that I have thought it worthy of a somewhat extended and minute description, which will be found in another part of this chapter.

On the west side of the Cincinnati arch the strata all dip westward, and ultimately sink beneath the Illinois coal basin. Toward the northern extremity o the arch the dip is northwest and more rapid; the strata here descending under the Michigan coal field. On the east side the easterly dip of the rocks is everywhere strongly marked, but greatest near the southern line of the state, where the axis is highest. Near the Lake shore the maximum dip probably does not exceed twenty feet to the mile, while on the Ohio it is double that, or forty feet. The rapidity of the dip also diminishes as we recede from the axis, and its uniformity is further broken by a series of subordinate folds imperfectly parallel with the great one. Following these various curves, the strata sink by a succession of steps or waves beneath the trough of the Alleghany coal field; the axis of which passes near but beyond our eastern border. The total dip in this direction is so considerable that the lowest stratum exposed on the crown of the Cincinnati arch is, on the eastern side of the state, buried about two thousand feet beneath the surface. East of Ohio all the rocks rise again, and not only the lowest exposed in our state, but even those which underlie them, crop out on the flanks and summits of the Alleghany mountains.

In addition to the east and west dips by which our strata are affected, they also exhibit well marked north and south dips, which, though less apparent, and hitherto unnoticed, are no less real and interesting. In the western half of the state, and especially along the summit of the Cincinnati arch, the dip of the strata is strongly northward; amounting to about 1000 feet, between the Ohio and the Lake. The surface of the Cincinnati group is, in Highland county, about 500 feet above Lake Erie, while, on the Lake shore it is nearly 400 feet below that level. It should also be said that these figures do not represent the entire dip; inasmuch as the crown of the arch is extensively eroded where it crosses the Ohio in Clermont County, so that we are unable to determine the original altitude of the surface of the Cincinnati group at this point, and hence the total northward dip. It could not have been less, however, than 1000 feet, and was probably more.

In the eastern half of the state a meridional dip is observable, quite as great as that last described, but toward the south. For example; the base of the Carboniferous Conglomerate at Little Mountain, Lake County,

is 600 feet above Lake Erie, while on the Ohio near Marietta it is over 600 feet below the level of the Lake; showing a southward dip of over 1200 feet in this interval.

This contrast in the north and south dips in the eastern and western portions of the state is due to the fact that the Cincinnati arch falls off toward the north and terminates in the low country beyond Lake Erie; while the eastern half of the state is occupied by the northern extremity of the great Alleghany coal field; an elongated boat shaped trough, in which the strata dip from the ends as well as the sides, toward the central portion.

The great diversity of level which I have shown to exist in the rocks of Ohio is, for the reasons before stated, but imperfectly exhibited upon the surface, and has given little variety to our topography except so far as it may have determined the courses of our draining streams, and hence the positions of our valleys of erosion. It would seem however to promise greater success to Artesian borings than has been attained, and hence the cause of the failures experienced becomes an interesting subject of inquiry. It is probably known to most persons that an Artesian well is one in which there is a constant flow of water from a subterranean source. Such wells can only be obtained where there is a peculiar and unusual arrangement of the underlying rocks, combined with a topography which affords a "head," or source of water supply, higher than the surface where the boring is made. The subterranean structure which gives rise to Artesian wells must be in some degree that of a basin in which porous and impervious strata alternate; the porous strata dipping down from some higher land where the water is absorbed, while impervious overlying rocks prevent its escape at a lower level. When, therefore, the impervious strata are pierced, the water rises through the artificial outlet and flows spontaneously as a fountain. So far as I have learned, the only successful Artesian wells in the state are those of Toledo, Bryan, and various other points in our north-western counties. These wells, however, derive their flow only from the *surface* of the rock, and deep borings—of which a great number have been made in this district—have never, so far as known, given rise to an Artesian flow of water. The Drift deposits in the north-western portions of the state deeply cover the slope of the rocky basin of Lake Erie. They consist for the most part of a thick sheet of impervious clay, beneath which is a stratum of sand, gravel, and boulders, lying upon the rock, and through which currents of water pass. It is easy to see how the water absorbed on the divide west of, and above, Bryan, percolates down beneath the clays, and rises to the surface at lower levels when they are pierced.

The Cincinnati arch in this region as elsewhere, is mainly composed of impervious limestones and its summit is lower than the surface where the borings have been made. Hence, though the dip of the strata is strongly northwest, the little water absorbed by them cannot possibly rise to the surface. In the central and southern portions of the state the geological structure is somewhat more favorable, and yet, as will be seen, it wants one element indispensable to success. The crown of the Cincinnati arch is several hundred feet higher than the valley of the Scioto, and the strata which compose it dip eastward even more rapidly than the surface. They would therefore certainly be water-bearing and would supply an artesian flow, provided some of them were porous, and others, overlying these, impervious. It unfortunately happens however, that they do not exhibit any such alternation. The mass of the arch is composed of limestones, first, the Corniferous, Waterlime, Niagara, and Clinton—which are but slightly water-bearing, and have no continuous impervious cover—then the Cincinnati group, a mass of compact limestones and shales, about 1000 feet in thickness, and it is plain that no water could circulate through these. Beneath the Cincinnati group, the Calciferous sandrock and Potsdam sandstone are porous and water-bearing strata, but they rise to the surface no where in our state, nor indeed to a level higher than the surface at any point where they could be reached by boring. Hence, it is vain to expect a supply of water from this source.

It is possible that borings made somewhere in the valleys which traverse our portion of the Alleghany coal basin may penetrate the Waverly group or the Carboniferous Conglomerate where the necessary conditions of water-head and impervious cover are supplied, and so an Artesian flow may be gained. The immense number of oil wells bored in these valleys, none of which, so far as I know, are Artesian, seem to prove, however, that failure will continue to be the general rule and success the rare exception in all efforts to obtain a spontaneous flow of water from wells sunk for this purpose.

The deep well at Columbus was bored in the hope of obtaining an Artesian flow from it, but, for the reasons given above, the effort was not successful. It afforded however most interesting information in regard to the strata which deeply underlie the state, both as respects their position and geological equivalence, and it will be again referred to in connection with both these topics.

STRUCTURE AND AGE OF THE CINCINNATI ANTICLINAL.

It has been long known to geologists that a line of upheaval passes from the south line of Tennessee, with a direction a little east of north, through Nashville and Cincinnati to Lake Erie. This line is marked by no conspicuous topographical features, but throughout its whole length the rocks are raised in a distinct arch, from which they dip away, on the one side under the Alleghany coal field, on the other beneath the coal basin of Indiana and Illinois. The bearing of this axis of elevation is nearly parallel with that of the folds of the Alleghanies, and it has been generally supposed that it was synchronous with them; in other words, that the date of its upheaval was subsequent to the Carboniferous and anterior to the Triassic period. No accurate analysis has, however, hitherto been attempted of the structure of the Cincinnati arch, and although frequent reference has been made to it by different geologists, no satisfactory description of this interesting feature in the geology of the Mississippi valley has yet been given to the public.

During the war I had occasion to traverse a large part of the states of Tennessee and Kentucky, and had opportunities for observing the relation of the rocks of the Cincinnati anticlinal at a great number of localities. These observations, combined with those of Prof. Safford of Tennessee, afford the means of forming some idea of the features it presents south of the Ohio river.

Since the organization of the present Geological Survey of Ohio, the structure of that portion of the Cincinnati arch which lies within the limits of our state has been the subject of special investigation by Prof. Edward Orton and myself. This investigation has resulted in bringing to light facts which have enabled us not only to determine accurately the date of the first upheaval and the details of structure of the Cincinnati axis, but have revealed to us much more than was before known of the physical geography of the Mississippi valley during the periods in which the Upper Silurian, Devonian, and Carboniferous strata were deposited. A brief *resume* of the observations to which I have referred, with such conclusions as seem legitimately deducible from them, will be given in the pages which follow.

A. STRUCTURE OF THE CINCINNATI ARCH SOUTH OF THE OHIO.

The general topographical and geological features of the Silurian area of Tennessee, with the relations borne to it by the exposures of the overlying strata, are very well given in the interesting and valuable report

made by Prof. Safford. From this report we learn that the *Central basin*, as Prof. Safford terms it, is underlaid by Lower Silurian rocks, corresponding in age to those of the Trenton and Hudson periods, in New York. These rocks are now extensively eroded, but once formed an arch or dome of moderate elevation, of which the anticlinal structure is still plainly discernible. On either side of the Lower Silurian area, the Upper Silurian, Devonian and Carboniferous strata are found, dipping northwest and southeast away from the central axis. They also dip, more gently, north and south from the geological summit of the Silurian area at Murfreesboro. Two sections on opposite sides of the arch, showing the contact of the Lower Silurian with more recent rocks, given by Prof. Safford, are of special interest as related to those observed in Kentucky and Ohio, by Prof. Orton and myself. Of the Tennessee sections, that on the northwest side of the arch, near the line between Davidson and Robertson Counties, is composed of the following elements:

		FEET.
1.	Silicious member of the Lower Carboniferous group. (Waverly)	268
2.	Black Shale. (Huron)	28
3.	Niagara Limestone	81
4.	Nashville group. (Lower Silurian)	...

On the opposite side of the arch, at Snow Hill, in DeKalb County, Prof. Safford reports the following section:

		FEET.
1.	Silicious member of the Lower Carboniferous group. (Waverly)	140
2.	Black Shale. (Huron)	45
3.	Nashville group. (Lower Silurian exposed)	303

The localities affording these sections are about fifty miles apart, the interval being occupied by Lower Silurian rocks forming the crown of the geological arch. From these sections we learn that on the flanks of the arch, in this region, the Upper Silurian strata have on the west side a thickness of 81 feet, the Devonian of 28 feet, an interval of 109 feet only, separating the Carboniferous from the Lower Silurian rocks. On the east side of the arch the Upper Silurian is entirely wanting, the Huron Shale—Devonian, and having a thickness of 45 feet—alone separating the Lower Silurian from the Carboniferous. Both east and west of the localities cited, the Upper Silurian and Devonian rocks attain greater thickness; showing that they rapidly diminish as they approach the crown of the arch. The Upper Silurian strata terminate in a feather edge, and the Devonian are so reduced as to render it very doubtful whether they ever stretched over; only one member being visible where

the formation is last observed. These sections show us then, that the upheaval of the arch took place before the deposition of the Upper Silurian rocks, and that during the Upper Silurian and through most, if not all of the Devonian ages, it formed an island raised above the surface of the ocean.

From my notes taken in the valley of the Cumberland, in Overton County, Tennessee, and Cumberland County, Kentucky, I take the following sections:—

Section at Burksville, Cumberland Co. Ky.

		FEET.
1.	Waverly Shales	250
2.	Black Shale. (Huron)	45
3.	Niagara Limestone and Shales	50
4.	Cincinnati group with *Orthis lynx*, *Strophomena alternata*, &c., to Cumberland River.	

Section on Sulphur Creek, Overton Co. Tenn.

		FEET.
1.	Carboniferous Limestone, capping hills.	
2.	Waverly	280
3.	Black Shale. (Huron)	3 to 20
4.	Cincinnati group.	

In the latter section we see that the Upper Silurian rocks have entirely disappeared, the Devonian nearly so, as *Orthis lynx* and *Strophomena alternata*, characteristic fossils of the Lower Silurian, may be obtained only five feet below the Waverly carrying Lower Carboniferous fossils. In this part of the Cincinnati arch, it is certain that neither the Upper Silurian nor the Devonian strata ever passed over it, but it was deeply buried beneath the Lower Carboniferous sea. The cliffs on either side of the Cumberland river are composed of strata of the latter age, and though now separated by the erosion of the valley, it is plain that they were once united.

In central and northern Kentucky the Lower Silurian area is greatly expanded. Its surface is now not very much elevated, and Muldrough's Hill, composed of Lower Carboniferous rocks, rises high above it. I have examined with some care the south-eastern, southern, and western margins of this area. On the southern side, the Burksville section is repeated in a great number of localities; the Upper Silurian and Devonian rocks holding, along the margin, a thickness of about 100 feet, nearly equally divided between Niagara and Huron. On the west side of the "Blue Grass" district these strata are seen resting upon the Cincinnati group near Lebanon and thence to Louisville. Following this line we

recede from the axis of the Cincinnati arch, and discover an increase in the development of the strata lying between the Waverly and the Cincinnati group. For example—the Huron Shale becomes doubled in thickness; the Corniferous Limestone and Waterlime come in—as may be seen at the Falls of the Ohio—and the Niagara is probably thicker than further south and east, though its lower surface is not visible in this vicinity. The Lower Silurian area is here nearly 130 miles in width, and though now extensively eroded and reduced in height, we have good reason for believing that this was once the most elevated portion of the arch, and one that has probably not been submerged since the close of the Lower Silurian ages. On any other supposition than this it becomes very difficult to account for these broad, depressed areas of Lower Silurian rocks, in Tennessee and Kentucky. They were beyond the reach of glacial action and do not form part of any connected channel of erosion. If they had ever been covered with Upper Silurian, Devonian and Carboniferous rocks, these, from their resistant character, would scarcely have been altogether removed. If, however, we accept the conclusion that the Lower Silurian strata have never been so covered and protected, the solution of the problem becomes easy. The Cincinnati group is mainly composed of *soft, calcareous strata,* such as are most readily acted upon by both chemical and mechanical agents. Exposure to the action of ordinary atmospheric influences only, to rain and winds, frost and sun, from the Silurian ages to the present time, would, therefore, inevitably have resulted in the removal of so much of the material of these old islands, that they would have been left in intaglio instead of relief. They would thus become just what they now are, basins, surrounded by elevated margins composed of later and more resistant strata once deposited around their shores and below the level of their surfaces.

Along the Kentucky river, from Frankfort to Nicholasville, and at Murfreesboro in Tennessee, the basal portion of the Blue limestone series is exposed to view, and if it was originally as thick at these points as elsewhere, not less than 800 to 1000 feet of the upper part have been removed. If, now, the missing masses were replaced, the Blue limestone areas would resume their original character; that is, they would be again islands rising above the plain that surrounds them. The Blue Grass region and the central basin of Tennessee are doubtless more extensive than the area of the old islands, as they have been considerably enlarged by erosion, but that the central portion of each formed an island through all the Paleozoic ages after the Lower Silurian, is, I think, a reasonable inference from the facts that have been stated.

B. STRUCTURE OF THE CINCINNATI ANTICLINAL NORTH OF THE OHIO.

The line of the Cincinnati anticlinal extends from the Ohio river near Cincinnati, in a direction a little east of north, to the Lake shore between Sandusky and Toledo. Throughout this interval it is marked by a distinct arch in the strata; which is, however, much more observable at its southern than at its northern extremity. In consequence of the erosion which all the region bordering the Cincinnati arch has suffered—an erosion that has been broad and general in its action—the line of the axis presents no conspicuous topographical feature; but it will be noticed that the direction of the draining streams, which follow the strike of the strata on either side, indicates that it once formed a water shed that gave the initial bearing to their flow. About Cincinnati the summit of the arch has been much more deeply and extensively removed than farther north, and yet this portion is still higher than its northern prolongation. We have good reason to believe, therefore, that this was originally the highest part of that portion of the arch that lies within the limits of our state, and that, in common with the Blue Grass district of Kentucky, the Blue limestone area about Cincinnati represents the most elevated portion of the ridge; that which has been the longest above the sea level, and therefore has suffered most from surface erosion. From this region the ridge—then a low mountain chain—fell off gradually to the north and vanished in the plain which skirted the Canadian highlands. This is indicated not only by the northerly dip of the rocks which form the arch, but by the bearings of the edges of the strata exposed on either side; the strike of these strata on the east side being nearly north and south from the Ohio to the Lake, while in the north-western portion of the state it is nearly northeast and southwest. These two lines of bearing would meet near the north shore of Lake Erie.

The physical structure of the arch is well shown by the observed dip of the rocks which compose and flank it. Prof. Orton, who has made a careful and discriminating study of that portion of the anticlinal which lies nearest to Cincinnati, has reported a number of observations on the altitude of the surface of the Cincinnati group within his district. From these we learn that the highest point of contact between the Cincinnati and Clinton groups observed by him, is near Lebanon, and is 441 feet above Lake Erie. From this point the dip for a distance of 35 miles

is northerly, and about four feet to the mile. On the northern margin of the state the rocks of the Cincinnati group are deeply buried and are concealed from observation. A boring on the crown of the arch here would give the level of the surface of the Cincinnati group, and would, therefore, enable us to ascertain, accurately, the northerly dip of the strata composing the anticlinal; but no such boring has been made. Wells have been sunk, however, on either side of the arch at its northern extremity; at the mouth of the Vermillion, at Sandusky, Toledo, Stryker, Whitehouse, &c. From these we learn that at points 20 or 30 miles from the summit of the arch, the surface of the Blue limestone series is about 800 feet below the Lake level. The Niagara and Helderberg rocks which overlie the Cincinnati group, are better exposed along the line of the anticlinal, and therefore afford means for a more accurate measurement of the northern slope of its crest. The central line, or axis of the arch, as Prof. Orton has shown, passes east of Cincinnati, and although the geological summit is removed by erosion, we find the highest exposure of the surface of the Niagara on the divide between the waters of the Little Miami and Scioto, in Highland county. Here the top of the Niagara is 557 feet above Lake Erie. At Genoa and Elmore, in Ottawa county, about 200 miles north, the surface of the Niagara, apparently on the summit of the arch, is 55 feet above the Lake. This shows a dip of 502 feet between the points of observation, but the descent of the crown of the arch must once have been more than this, as near Cincinnati the arch is truncated, and our point of observation on the surface of the Niagara in Highland county was originally some distance down its eastern slope.

The east and west dip of the rocks forming the Cincinnati arch is, naturally, much more rapid, and, although the strata which flank it are soon deeply buried, we are fortunately able by consulting the records of borings, to determine their position at points which show very clearly what the general features of its transverse section are.

As has been mentioned, the breadth of the eroded crown of the arch in Kentucky is nearly 130 miles. When, on coming northward, we enter Ohio, we find it already much narrowed, and yet the surface exposures of the Blue limestone group form a triangle, of which the base, on a line drawn east and west through Cincinnati, is about 90 miles broad, the south-western angle reaching far into Indiana. On either side of this area the corresponding strata dip rapidly away from the axis; so rapidly indeed, that if carried up at the same angle till they met above Cincinnati, they would form an arch fully 1000 feet in height.

Whether they ever did meet we shall perhaps never learn with certainty, but there are some facts which render it probable that they did not, as will be shown on another page. We can assert, at least, that if the Upper Silurian and Devonian rocks did once cover the Cincinnati arch, the angle of dip which they exhibit on its flanks was not continued; for from the summit of the Cincinnati hills no more than 200 or 300 feet of the *top* of the Blue limestone series has been removed, and the strata of this group over most of the breadth of the arch, as Prof. Orton shows, are nearly horizontal.

North from Cincinnati, as has been remarked, the breadth of the anticlinal rapidly diminishes. The outcrops of the Corniferous limestone which may be said to form its base on either side, and which in Kentucky are separated by an interval of more than 150 miles, near the Lake shore are within 50 miles of each other.

On the Ohio, the dip of the rocks which flank the axis is probably greater on the east side than on the west. In other words, its eastern slope is more abrupt than its western. On this point, however, further observations are required in Indiana. Careful sections made along the line of the railroads leading from Cincinnati to Indianapolis would determine this question with accuracy; for they would be made in lines nearly at right angles with that of the axis of the anticlinal. A section furnished me by David Christie, Esq., taken by himself along the Ohio and Mississippi railroad, from Cincinnati to the west line of Indiana, gives the following rates of dip of the strata:

	FT. PER MILE.
Dip of the surface of the Lower Carboniferous Limestone	8.6
" " " Waverly group	9.1
" base " Huron Shale	11.1
" surface " Niagara group	12.5

It should be remarked, however, that this line of observation is not at right angles to the axis of the Cincinnati arch, so that it is probable that the figures given are considerably less than such as would represent the true north-westerly dip of the strata. On or near the line of Cincinnati, the dip of the surface of the Blue limestone eastward, as given by Dr. Locke, is 37.4 feet per mile. Observations made by Prof. Orton and myself on the dip of the base of the Huron shale from Samantha—where its most western outlier is found—to the eastern margin of the county, give a dip of about 35 feet to the mile. Further north we have a more accurate measurement on a more extended line. At Bellefontaine, in Logan county, the base of the Huron shale is 670 feet above Lake Erie,

the point of observation being about the crown of the arch. At Columbus, 50 miles distant in an air line southeast, the base of the Huron shale is 65 feet above Lake Erie; giving a dip of 605 feet, or 12 feet to the mile. The dip eastward from Bellefontaine to Delaware, distant in an air line 36 miles east, is 402 feet, or about 11 feet to the mile. Observations at intermediate points are required to determine how this dip is distributed, but it is certain that near the summit of the axis the descent is much more rapid than farther eastward, and it would also seem that the line of greatest dip runs south of east.

If now we compare our observations on the elevation of the surface of the Cincinnati group in the south-western part of the state with the level of the same geological horizon at Columbus, as measured by the State House well, we get the following results:

Surface of Blue limestone near Lebanon	441 feet above Lake Erie.
" " " in Columbus well	721 feet below "

which gives a dip of 1167 feet in a distance of about 70 miles by air line, in a northeast direction; or 16.6 feet to the mile.

Prof. Orton states that the surface of the Cincinnati group at High Banks, near Troy, in Miami county, is 438 feet above low water in the Ohio; or 305 feet above Lake Erie. Comparing this with the assumed level of the surface of the Blue limestone in the State House well, we have a dip indicated of 1031 feet; or—since the points of observation are about 60 miles apart in an air line—17 feet to the mile; the direction being nearly east.

It may be thought that any conclusions based on comparisons of level made with the register of the State House well are of doubtful value; and yet this record was kept with such unusual care and minuteness—specimens of the borings having been preserved from so many different points—that the data furnished by the well seem to me to be worthy of confidence. If we accept them we must conclude that the dip of the surface of the Blue limestone is considerably greater than that of the Corniferous group. It seems inevitable that we should get this result, from the fact that the Corniferous and the Helderberg limestones are introduced, and acquire a thickness of 300 feet, between the points of observation in Highland county and Columbus. The partial filling of the trough lying east of the Cincinnati axis, by the formations I have enumerated, would necessarily diminish the dip of the Huron shale which was deposited upon them.

The transverse section of the northern extremity of the Cincinnati

arch is revealed to us by no such exposure as that in the valley of the Ohio. The crown of the arch is here brought down to the level of the Lake, and the surface outcrops afford very imperfect means for the measurement of the dip. The well borings that have been referred to, give us, however, some interesting information. In nearly all of these, the red shales of the Clinton and Medina form a distinctly marked horizon, which fixes, within a few feet, the surface of the Cincinnati group. In the well bored at Toledo the red shale was struck at the depth of 800 feet. This well was begun at a point 40 feet above the Lake, and passed through 100 feet of Drift, then through the Upper Silurian limestones—Waterlime, Niagara, and Clinton—here considerably thicker than farther south. The crown of the arch is at Genoa, Elmore and Washington, distant 15 to 20 miles from Toledo in a south-easterly direction. It is there formed by the surface of the Niagara, which has an elevation of about 50 feet above the Lake. At Waterville, 15 miles southwest from Toledo, a well, begun in the Waterlime, reached the Medina at 400 feet, the surface of the Cincinnati group being distinctly marked at 460 feet. The margin of the Niagara is here but about five miles distant. The Toledo well indicates an extremely rapid dip on the northwest side of the axis,—probably not less than 40 feet to the mile—but from a want of accurate knowledge of the thickness of the Niagara, it cannot be measured with absolute certainty. This rapid dip is also shown upon the surface by the narrowness of the belts of outcrop of the Corniferous and Waterlime near Toledo. The crown of the arch in this vicinity is broad and shows at least two distinct folds by which the Niagara is brought to the surface.

East of the anticlinal, wells have been bored at Sandusky and the mouth of the Vermilion. The records of the Sandusky well were not kept with sufficient accuracy to be of much value to us in this connection, but the depth at which the gypsum of the Salina group was struck indicates an easterly dip of something like 18 feet to the mile. The Vermilion well terminated in the Medina, here a red sandstone, at the depth of 800 feet below the Lake level. The distance of the mouth of the Vermilion from the nearest outcrop of the Niagara is about 40 miles, and if we assume the thickness of the Niagara and Clinton, in this portion of the state, to be what the well-borings indicate, about 400 feet, this would give a dip of 10 feet to the mile.

These borings seem to show that at its northern extremity the dip of the rocks on the west side of the anticlinal is more rapid than on the east; an opposite condition from that which prevails farther south.

C. GEOLOGICAL STRUCTURE AND HISTORY OF THE CINCINNATI ARCH.

In the description that has been given of the physical structure of the Cincinnati axis, the strata which form it have been so frequently referred to, that no farther analysis of its geological structure would seem to be required. I shall be compelled, however, to give a brief review of the elements which compose the anticlinal, in order that the records they afford, both of its formation and degradation, may be intelligently read.

The geological and topographical features of that portion of the state which surrounds Cincinnati are minutely and accurately described in the report of Prof. Orton, which forms a part of this volume. I will therefore refer to that report for all details of the structure of this part of the anticlinal, and will only remark in passing, that as far north as Dayton the whole crown of the arch is occupied by the outcrops of the Cincinnati group, here deeply eroded to form the valleys of the two Miamis. Around the margin of the Blue limestone area extends a broad belt formed by the exposures of the Clinton and Niagara groups. In Clarke, Champaign, Shelby, Darke and Mercer counties the Niagara is the surface rock over the entire breadth of the anticlinal; and thence northward to the Lake shore it occupies the crest in a nearly continuous, though somewhat irregular and tortuous line of outcrop.

Over most of the northern half of that portion of the axis which lies in Ohio, the Waterlime group underlies the surface, in Hardin county forming a band which stretches entirely across from side to side. North and south of this point the Helderberg area is divided into two or more belts by the exposures of the Niagara.

From Pickaway county to Sandusky, and from Sylvania up the Maumee to Paulding, the sides of the arch are flanked by belts of the Corniferous limestone. North of Columbus, on both sides of the arch the Corniferous is overlaid by a thin sheet of Hamilton. Still further removed from the central line, we have on the east and northwest broader belts of the Huron shale. On the crown of the arch in Logan county an island of Corniferous limestone capped with Huron shale has been left by the erosion of its connections.

I have now enumerated the elements which enter into the composition of the Cincinnati axis, but there are some features presented by each formation which require notice, as they form the record of some of the most important incidents in its history.

1. *Cincinnati Group.* The axis of the arch, as shown by Prof. Orton, passes east of Cincinnati through Bethel in Clermont county. Here the strata rise nearly 100 feet higher, geologically, than at Cincinnati, and from this point they dip both east and west. Though now denuded of all the central portion of the Blue limestone area, Prof. Orton finds satisfactory evidence that the Lebanon beds, the topmost portion of the series, once stretched over its entire breadth, and therefore, that the Cincinnati group was horizontally deposited before the first elevation of the arch.

2. *Medina and Clinton Groups.* The Blue limestone series is overlaid by red, blue, and mottled calcareous shales which occupy the position of the Medina sandstone, and yet have yielded no fossils by which their identity with this formation can be demonstrated. From their soft and yielding nature, these shales have been removed wherever they were fully exposed to erosion, and are only found where they have been protected by the overlying Clinton limestone. The Clinton group has been identified by numerous fossils, and there can be no question of its age. In thickness it is extremely variable, diminishing from 40 feet in Greene county to 15 feet at Dayton. In Adams county the interesting discovery was made by Prof. Orton, that a part of the Clinton is formed by a conglomerate of well rounded limestone pebbles and worn fossils of the Blue limestone series. The importance of this discovery will be readily appreciated, as it proves that before the deposition of the Clinton, the Cincinnati group was consolidated into rock and raised into cliffs and shore lines which were eaten away by the waves at the ocean level to form a pebbly beach. *Here we have an indubitable record of the elevation of the Cincinnati arch between the Upper and Lower Silurian ages,* and proof that it is far older than the Appalachian system with which it has been commonly associated.

Owing to the extensive erosion that this portion of the arch has suffered, it is impossible for us now to trace the line of the shore which bounded the Clinton sea. The rapid thinning of the Clinton limestone at Dayton indicates, however, that it ran not far distant from that locality. As we shall see farther on, the abundant evidence of the continued submergence of the axis northward, seems to prove that it here swept around the north end of an old Silurian island, which in the Clinton epoch stretched far southward into Tennessee. It will be remembered that the Clinton is wanting in all the sections taken on the flanks of the arch in both Tennessee and Kentucky; from which we may infer that all such portions of it as are exposed to view in that region were above the ocean level during the Clinton epoch.

3. *Niagara Group.* The Niagara group forms a marked feature in the geology of the Cincinnati axis in Ohio, but becomes constantly less important going southward. The best exposures of it which we have are in Highland county, where it attains a thickness of 275 feet, consisting of

		FEET.
1.	Hillsboro sandstone	30
2.	Niagara limestone	180
3.	Niagara shale	60
4.	Dayton limestone	5

Of these, the sandstone which forms the summit of the group seems to be a local deposit, as it is scarcely met with outside of Highland and Adams counties. We have no means of accurately measuring the thickness of the Niagara group in the northern part of the state, as only its upper portion is exposed, and in the well sections it is not easy to draw the line between that and the overlying Helderberg and Corniferous limestones. The color of the Niagara is, however, usually a light yellow, and its texture coarse, porous, sometimes sandy; so that it is oftener than otherwise called a sandstone by the well borers. Judging by the space occupied in the well sections by rocks having the character of the Niagara group, I am led to believe that in the northern part of the state it attains a thickness of about 350 feet. The Hillsboro section shows therefore, that the Niagara has there nearly its normal thickness. In Adams county it is represented by Prof. Orton as only 190 feet thick, and I have nowhere observed it in Kentucky or Tennessee attaining a thickness of over 100 feet. It covers the Clinton, however, where the latter formation is thinning out on the old shore line, with such a depth of sediments that it shows clearly a considerable depression of the land or elevation of the sea level, during the Niagara period in Ohio; as was the case in New York. Whether the Niagara submergence covered all the Ohio portion of the old Silurian island we have no means of determining with certainty, as erosion has obliterated the record. By reference to the Kentucky and Tennessee sections quoted on preceding pages, it will be seen that the Niagara sea did not cover all portions of the Cincinnati arch south of the Ohio river.

4. *Helderberg Group.* As has been mentioned, the Waterlime certainly once covered all portions of the northern extremity of the Cincinnati axis. It now reaches over from side to side at one point with its normal thickness, and where the Niagara is exposed along the crown of

the arch, the Waterlime has undoubtedly been removed by erosion. As we move southward, however, along the sides of the arch we find the Waterlime growing gradually thinner, until in southern Kentucky and eastern Tennessee no traces of it are recognizable. Going from the base toward the summit of the arch in Southern Ohio, this thinning of the Waterlime is still more evident; as at Lexington it diminishes from 100 feet to 15 feet in two miles. (Prof. Orton.) Going still further westward, it entirely disappears, letting the Huron shale down directly on to the Niagara. From these facts we learn that the sea level in the Helderberg period was considerably lower than when the Niagara sediments were deposited, and was nearly the same as during the deposition of the Clinton. The absence of the Waterlime from the strata which flank the arch on the east in Kentucky and Tennessee, proves that a large land area existed there in the Helderberg period.

5. *Corniferous Limestone.* The belts of outcrop of the Corniferous limestone which run along the base of the Cincinnati arch are now separated by an interval of from 50 to 100 miles, and we should be without proof that the northern extremity of the arch was covered by the Corniferous sea, were it not for the island which occupies its crest in Logan county. This shows plainly that a sheet of Corniferous limestone once covered all portions of the axis from this point northward. We fail to find any traces of the Corniferous, however, on the east side of the arch further south than Pickaway county, where it thins out westward to a feather edge on the Waterlime. It undoubtedly extends further southward, as traces of it are found in Kentucky on both sides of the axis, but its margin is, in southern Ohio, overlapped and concealed by the Huron shale which extends much further westward. The limited reach of the Corniferous limestone toward the south and on the flanks of the Cincinnati arch, shows that during the Corniferous epoch, the relative level of the sea was much lower than in the Niagara, and somewhat below what it was in the Helderberg period. It will be noticed, however, that the island of Devonian strata in Logan county forms one of the highest portions of the state; the surface of the Corniferous limestone being there 670 feet above the Lake. The level of the same formation where it runs to an edge and is overlapped by the Huron shale, is 200 feet lower than this; a fact which proves either that the northern portion of the Cincinnati arch was, in the Corniferous period, relatively lower than it now is, or that the Corniferous belt at the eastern base of the arch in Pickaway county had suffered extensive erosion before the deposition of the Black shale. The latter supposition is hardly probable, as

the Corniferous limestone in this region shows no distinct marks of erosion. The probability seems, therefore, to be, that the relative levels of the Corniferous limestone in Pickaway and Logan counties were once quite different from what they now are.

There are some other facts in regard to the deposition of the Corniferous limestone which are worth reporting in this connection.

In Delaware and Marion counties, at the junction of the Corniferous with the underlying Waterlime, the former limestone is largely composed, locally, of rolled pebbles of the latter; from which we may infer that there is a slight unconformability between the Devonian and Upper Silurian groups, just as between the Upper and Lower Silurian,—indicated by the Clinton conglomerate—and that the Waterlime here formed a shore to the Corniferous sea, just as the Cincinnati group did to the sea of the Clinton epoch.

We shall probably find that like other mountain ranges, the Cincinnati axis continued to be a line of disturbance through several geological periods. The want of conformability exhibited by the strata which flank it, is apparently due in part to variations in the inclination of the sea bottom on which they were deposited, and not altogether to oscillations of sea level caused by continental elevations and depressions.

The Waterlime on the islands in Lake Erie was evidently much shattered by disturbances which occurred after the deposition and consolidation of this formation. The fragments were subsequently reunited and a breccia formed; the interstices between the displaced blocks being sometimes filled with celestine and native sulphur, probably deposited by thermal waters; and yet, so far as observed, the Corniferous limestone shows no evidence of having been disturbed by the forces which locally shattered the Waterlime. They therefore seem to have done their work before the Corniferous limestone was deposited.

In the Coal Measures we find satisfactory evidence that many of the changes of strata were caused by changes of level, not continental but local, and produced by the varying curvature of the bottom of the trough between the Cincinnati axis and Blue Ridge.

I venture to call attention here to the fact more fully reported elsewhere, of the finding in the Corniferous limestone at Sandusky and Delaware, many floated fragments of land plants, among which are trunks of tree ferns, branches of *Lepidodendron*, &c. With the knowledge that the study of the Cincinnati arch has given us of the island which rose above the Corniferous sea, and with what we know of the reach of that sea in other directions, we can form some idea as to where these land plants came from. As I have elsewhere suggested, the Corniferous

sea was a warm one, permitting the growth of coral reefs as far north as the islands of Lake Erie. The climate of the Cincinnati and Nashville island must, therefore, have been warm enough in the Corniferous period to permit the growth upon it of a tropical vegetation. This island could not have been more than 100 miles distant from Delaware, and land plants could easily drift to that point, and even to Sandusky, from its shores. The considerable number, good preservation, and character of the plants found in the localities mentioned, seem to indicate that they came from a near and more southern land. The shores of the Devonian *continent* were 500 miles away toward the east and north, and it is quite improbable that these plants should have come from there. We are justified in concluding, therefore, that they formed part of the vegetation which covered the surface of the island (or islands) whose history we have been tracing. From the dissemination of these plants we may infer that a current from the south swept the eastern shore of our ancient Atlantis, and this current may have extended the northern reach of coral reefs.

It will perhaps appear strange that with the well-marked shore lines which have been discovered, and the many proofs we have of the advance and recession of these shore lines, we have not found a larger amount of mechanical sediments in the strata that have been enumerated. It should be remembered, however, that all the materials composing the nameless island to which reference has so frequently been made, are calcareous, and there was nothing there to make sandstone or quartz conglomerates of. Conglomerates of *limestone* pebbles were formed, as we have seen, precisely as they are now forming on the limestone islands of Lake Erie. The Hillsboro sandstone, and the thin layer of Oriskany which lies at the base of the Corniferous limestone, are probably edges of the great sheets of mechanical sediments of the same date, which are found in the Alleghany belt, and are of eastern or northern origin.

6. *Huron Shale.* The period of the deposition of the Huron shale was evidently one of submergence, as it reaches farther up on the flanks of the Cincinnati arch in southern Ohio than any other formation except the Niagara. Whether it covered all our portion of the arch cannot be determined, as it has been so easily acted upon by eroding agents that it has been removed from nine-tenths of the area it once occupied. The Logan county island, of which the highest points are covered with Huron shale, proves conclusively that it once extended over all the northern portion of the Cincinnati arch. As we go southward into Kentucky and Tennessee, we find the Huron shale much thinner than in

Ohio, but a constant feature in all the sections afforded by outcrops of the rocks flanking the Lower Silurian areas. In many places it reaches beyond the Niagara, and we may therefore conclude that the submergence of the land during the Huron epoch was more general than at any previous time. It will be remembered, however, that in some localities in northern Tennessee, I observed the Huron shale reduced to a thickness of three feet, this alone separating the Lower Carboniferous rocks from the Lower Silurian. It is therefore almost certain that not all portions of the Cincinnati arch were brought beneath the sea during the Huron epoch.

7. *Lower Carboniferous Group.* Since surface erosion has removed all the records from the interior of the Lower Silurian areas, we have no means of positively determining whether they were entirely covered by the Carboniferous sea, and yet it is certain that the sea level, in that period, was relatively higher than in any of the epochs of submergence which have been enumerated. In Ohio, the Huron shale, at the point where it approaches nearest to Cincinnati, has a thickness of 250 feet; only 100 feet less than in the Scioto valley. Its present western outcrop is therefore considerably remote from the shore line which limited its reach. It is covered, however, in the localities referred to, by 100 feet of Waverly shales, so that it may be said that the extension of the Waverly in Ohio, nearly, if not quite, equals that of the Black shale. In Kentucky and Tennessee the proofs of the submergence of the Cincinnati anticlinal in the Lower Carboniferous period, are much more striking. For example; the Blue Grass area of central Kentucky is overlookod on the southwest by the bold escarpment of Muldrough's Hill, which rises high above it. Muldrough's Hill is, however, only the cut edge of the Lower Carboniferous plateau which occupies central and southern Kentucky, and which, except where cut by the deep and narrow gorge of the Cumberland river, stretches continuously from the Cumberland mountains to the Illinois coal field. This portion of the anticlinal is therefore deeply buried under Lower Carboniferous sediments, first, with the Waverly shales 250 feet in thickness, and above these, with an equal mass of Lower Carboniferous limestone. In Tennessee the Lower Carboniferous plateau skirting the Cumberland mountains forms the eastern rim of the topographical basin of the Silurian area, while corresponding escarpments of the same formation border it on the south, west and north. We may infer from these facts; first, that the Cincinnati arch was more deeply submerged during the Lower Carboniferous than at any previous period; second, that the submergence was greatest towards the

south; third,—from the entire absence of the massive, resistant strata of the Lower Carboniferous group in the central portions of the Blue limestone areas—that they were never completely covered by them.

The Lower Carboniferous limestone marks the period of greatest depression of the land, or elevation of the sea, which took place during the Carboniferous age. The reach of this limestone measures the extent of the open sea of the period, and its thickness, at the same time, measures the depth of the sea and the duration of the submergence. In Kentucky and Tennessee the Lower Carboniferous limestone is, in some localities, 500 feet in thickness. It reaches northward, constantly thinning, until it terminates in a feather edge in the trough of the Alleghany coal field about the southern line of Pennsylvania and the central part of Ohio. This thin margin of the limestone is composed of the Upper or Chester division only, of the limestone mass. This shows that the submergence was progressive from the south northward, and that the area of clear water reached only the limit I have mentioned. As the relative relief of the Cincinnati arch was at least as great in the Carboniferous age as now, it seems quite certain that the Carboniferous sea did not cover its northern portion.

These facts apparently help us to a solution of the question so much discussed, "Were the Alleghany and Illinois coal fields ever united?" The proof seems to be abundant that they were not. It will be remembered that in the epoch of the Coal Measures the Carboniferous sea had retreated, and that as far south as Alabama continuous land conditions prevailed during the deposition of each coal stratum. It is therefore certain that the Cincinnati arch was raised above, and that it somewhat widely separated, the great coal marshes.

But it will be said that the limestones inter-stratified with the coal seams mark periods of submergence in the Coal Measure epoch, and that the sea in these intervals might have rolled completely over the Cincinnati arch. Prof. Rogers even sees in the westward thickening of the Coal Measure limestones in Pennsylvania, evidence of a widespread open sea at the west during their deposition. Our observations in Ohio prove, however, that Prof Rogers was mistaken in the facts, and therefore, in his conclusions; for the limestones of the Coal Measures are most numerous and thickest in the centre of the basin, thinning out on the west as on the east. Even the great limestone overlying the Pittsburgh coal—that upon which Prof. Rogers specially based his conclusions—after passing the centre of the trough diminishes rapidly in force, and is largely replaced by mechanical sediments as the western margin of the

coal field is approached. These facts prove that the Alleghany coal field was in the Coal Measure epoch as it is now and has always been since the Lower Silurian age, a synclinal trough. In the Upper Silurian and Devonian ages this was an arm of the sea, bounded by the Blue Ridge on one side and by the Cincinnati axis on the other. During the limestone making intervals of the Coal Measure epoch this trough was still occupied by an arm of the sea, but was then a gulf or tongue, of far more restricted dimensions than before. Of this gulf the Cincinnati arch was the western shore, and one which rose high above it. The degradation of this shore—as I shall show more fully in another place—contributed a large part of the mechanical materials inter-stratified with the limestones and beds of coal; the Carboniferous and Waverly conglomerates and sandstones supplying the materials for the conglomerates and sandstones of the Coal Measures on the western and northern sides of the basin.

It is perhaps possible that a connection once existed between the Illinois and Alleghany coal fields in southern Kentucky, along the line of depression between the Kentucky and Tennessee Lower Silurian areas. But of this we have no proof. The interval which separates the Coal Measures is very wide even where the Carboniferous limestone is continuous. The probabilities are therefore, that these two basins were entirely disconnected; but if they were anywhere connected it was at the southern end of the Cincinnati axis, where the state of Alabama now is, and where the coal strata are covered by the Mesozoic and Tertiary rocks of the Gulf coast.

The Islands in Lake Erie. Among the indirect consequences of the upheaval of the Cincinnati arch we may include the group of islands in the west end of Lake Erie. Such islands are exceptional in our lower lakes, of which the basins are excavated in strata usually little disturbed and of uniform composition over large areas. Our lakes are monotonous in outline and surface because each is the product of a single great cause operating upon a comparatively simple and homogeneous geological structure. Hence the origin of the islands referred to forms an interesting subject of investigation. I am not aware that any theory has been proposed to account for their existence, but now that their geological structure is known, when viewed in connection with the Cincinnati axis, their origin is easily explained.

In the description of the Cincinnati axis which has been given on the preceding pages no effort has been made to trace it beyond the south shore of Lake Erie. North of this line the geology is obscured, first, by

the waters of the lake, and second, by the thick and continuous sheet of Drift clay which covers the rocks that underlie the low and level country beyond the Lake. We have every reason to believe however, that the great fold which is so strongly marked within the limits of our state, reaches, though in constantly diminishing force, far into the Canadian territory, and it is even probable that the line of disturbance which has been noticed by the Canadian geologists in the vicinity of the Enniskillen oil region, is only the northern prolongation of the Cincinnati axis. The rocky strata which form the bottom of the west end of Lake Erie seem to have been considerably affected by it; and here it brought up the massive limestones of the Devonian and Upper Silurian series in such a way as to form a transverse barrier across the present Lake basin. East of this barrier the Huron and Erie shales and the Waverly group must have been left at a lower level in nearly horizontal sheets with an average thickness of more than a thousand feet of soft and yielding material. All the middle and eastern portions of the Lake basin have been excavated in these last-mentioned strata, mainly by a glacier moving from the north-east toward the south-west, or rather, along the major axis of the Lake. When, in the progress of this glacier, it reached the line of the Cincinnati axis, after the removal of the overlying shales it encountered a barrier of massive and resistant limestones which constituted a formidable impediment in its way; one that opposed an obstinate resistance to its eroding power, and thus was left in comparative relief. In my judgment, the islands in Lake Erie are parts of this ancient barrier. They are all wrought by glacial action out of the Corniferous limestone and Waterlime; of which the latter here forms the crown of the anticlinal. They are separated by comparatively shallow channels, and all of this part of the Lake basin is much less deeply excavated than the middle and eastern portions. On the north shore of the Lake the arch has become so low that the Corniferous and Waterlime sink out of view, and in the central portion of the peninsula between Lake Huron and Lake Erie the Hamilton shales and limestones form the rock surface beneath the Drift clay. The details of the origin and mode of formation of the islands will be more properly given in that part of the report which is devoted to the consideration of their geology.

SECTION II. THE GEOLOGICAL SERIES.

SILURIAN SYSTEM.

The order of succession of the rocks of Ohio will be seen at a glance by reference to the accompanying engraved section. From this, as well as from the allusions made to our geology on the preceding pages, it will be understood that the oldest rocks exposed within the limits of our state, or reached in any borings that have been made here, belong to the Silurian system; which—divided into two groups, the Upper and Lower Silurian—is overlaid by Devonian rocks, and these in turn by those of Carboniferous age; the latter forming the summit of our geological column, with the exception of the superficial materials representing the Drift.

In order that the readers of this report may obtain a more complete knowledge of the geological structure of the State, I now propose to take up each member of the series in order, and to give a description of the geographical area occupied by its outcrops, its prevailing lithological features and its characteristic fossils.

POTSDAM AND CALCIFEROUS GROUPS.

As has been already mentioned, the oldest rocks which come to the surface in our state, form that division of the Lower Silurian system known as the Cincinnati group; and we might begin our review with this formation, were it not that a deep boring made at Columbus, has revealed to us something of the nature and thickness of the strata which underlie the Cincinnati series; those which are exposed in many parts of the United States, and such as are known to form the real base of the Silurian system. It seems desirable, therefore, that they should receive at least a passing notice.

The important facts revealed by the State House well at Columbus will be best gathered from the register of this well; a synopsis of which is given below, with an explanation, as far as possible, of the geological equivalence of the strata passed through.

Synopsis of the Register of the State House Well, Columbus, Ohio.

Date.	No.	Thickness.	Depth struck.	Rocks passed through.	Feet bored per day.	Remarks.
1857. Nov. 4	1	123	....	Clay, sand and gravel...	......	Well tubed with 6 in. iron pipe to the rock. Inside of this a 4 in. pipe sunk several feet into the rock.
Dec. 2	2	15	123	Blackish shale............	7	
Dec. 11	3	138	138	Gray limestone with bands of chert.........	5	Struck current of water at 150 ft. which washed away borings to 242 ft. Found sulphur water at 180 ft.
1858. Jan. 14	4	2	276	Very gritty rock..........	2	Water raised 5 feet.
Jan. 15	5	486	278	Limest'es, light colored & sandy ab've, darker & argillaceous below.	10	Found salt water at 675 ft.
Mar. 20	6	162	764	Red, brown and gray shales and marls......	12	Borings impregnated with salt.
Apr. 8	7	1058	926	Blue and greenish calcareous shales..........	13	Progress per day ranging from 1 to 25 feet; much impeded by crumbling of shale. Strata harder below. Borings salt.
1859. June 25	8	475	1984	Light colored, sandy magnesian limestone.	4½	Water continues saline.
1860 June [illegible]	9	316?	2459	"Whitish sandstone" (calcareous)	4	Probably alternating bands of sand and lime above. No borings preserved below 2570 ft; mostly washed away by water.
Oct. [illegible]	......	....	2775.4	Present bottom of well, in sandrock?............	......	

Geological Section of the Strata penetrated by the State House Well.

No.	Thickness.	Character of Rocks.	Their probable Geological equivalents.	
1	123	Clay, sand and gravel.	Alluvial and Drift deposits in old valley of the Scioto.	Drift.
2	15	Blackish shale.	Huron shale, (Portage and Genesee shales), base only.	Devonian.
3	138	Gray limestone with bands of chert.	Corniferous limestone.	
4	2	Very gritty rock.	Oriskany sandstone.	
5	486	Limestones, light colored and sandy above, darker and argillaceous below.	Helderberg, Niagara and Clinton limestones.	Upper Silurian.
6	162	Red, brown and gray shales and marls.	Clinton, Medina and upper part of Cincinnati group.	
7	1058	Blue and green calcareous shales and limestones.	Cincinnati group, with perhaps Bla'k river, Birdseye and Chazy limestones.	Lower Silurian.
8	475	Light drab, sandy, Magnesian limestone.	Calciferous sandrock of N. Y., Magnesian limestone group of Missouri.	
9	316	White sandrock (calcareous.)	Potsdam sandstone.	

Most of the strata enumerated in the above section rise to the surface in the western part of the state, and will, therefore, be so fully described on succeeding pages that no lengthy reference to them is required here. It is, however, interesting to observe that between numbers 5 and 8 we get the only measure which we have, of the interval between the base of the Niagara and the base of the Blue limestone series, namely 1212 feet. Just how much of this interval is occupied by the Clinton and Medina, and how much by the Cincinnati group it is impossible to say, as the red color of the Clinton and Medina may have been transmitted to the upper portions of the blue and green shales below, and, therefore, the thickness of the Clinton and Medina exaggerated. It is possible, however, that the Medina has considerably thickened in the distance between its outcrops near Cincinnati and Columbus. We may at least infer that the calcareous mass, of which nearly 800 feet in thickness are exposed in the valley of the Ohio, is not less than 1000 feet thick; and we may also infer from the specimens preserved, and from the rapid progress made in the boring, that very little of this mass is anywhere in Ohio made up of thick and compact strata of limestone; in other words, that the lithological character of the group is throughout nearly what we find it to be in the exposures about Cincinnati.

At the depth of 1984 feet the auger evidently passed the bottom of the Cincinnati series and entered a totally different formation. This is described in the record as being a light colored granular limestone, and I found it to be not only magnesian, but to contain a large amount of silica. There can be no reasonable doubt, therefore, that this formation is the "Calciferous sandrock" of New York, and the equivalent of the "Magnesian limestones" of Missouri. After passing through 475 feet of this light colored limestone, a whitish sandstone was entered. All the material brought up from below this point is of the same general character, though nothing was obtained from the well within 150 feet of the bottom; currents of water having carried away the borings. I have inferred that this lower sandstone is the equivalent of the Potsdam of New York.

The Calciferous sandrock—if I am right in the identification of it—has in Ohio a thickness of nearly 500 feet, and is intermediate in character between the New York and Missouri phases of the group; containing more lime and magnesia and less sand than the former, and yet more siliceous material than is found in the latter. This is precisely what we might have expected, and shows that this formation becomes gradually more calcareous in passing westward and receding from the ancient land; following the law which seems to prevail among all our palaeozoic formations.

The temperature of the bottom of the Columbus well when it had reached the depth of 2575 feet, was tested by Prof. Wormley with the following interesting results, which I give in his own words.

"A Walferdin's thermometer, placed in a glass tube filled with water, and this inclosed in a strong iron case also filled with water, was lowered to the depth of 2475 feet, where it remained for twenty-four hours. It was then sunk to the bottom of the well, a depth of 2575 feet, where it remained for twenty minutes. Upon the withdrawal of the instrument, it was found to have registered 88° F. Assuming this to be the temperature of the bottom of the well, and also assuming as correct data, that the temperature is uniformly 53° F. at a depth of 90 feet, we have an increase of 1° F. for every 71 feet."

By adopting a point 50 feet from the surface as the horizon of invariable temperature, and that, for Columbus at 50° F., it will be found that the increase in temperature to the depth of 2575 feet is at the rate of 1° F. for every 66 feet of descent. It should be said, however, that recent experiments made in Europe have proved that unless the thermometer is so encased as to be protected from the pressure of the column of water, the registered temperature is liable to be somewhat erroneous. It is desirable, therefore, that the temperature of the well should be taken by a thermometer so constructed as to be free from this source of error. Such an instrument has been obtained, and if access can be gained to the well, its temperature will be again measured. It may be of interest to note, in this connection, the fact that in the deep wells bored at St. Louis and Louisville—the first 3843.5 feet, the second 2086 feet deep—the temperatures were respectively 105° and 82½°. It is *reported*, however, that the maximum temperature (107° F.) observed in the St. Louis well was reached at the depth of 3029 feet; 814.5 feet above the bottom. A result so anomalous as this requires confirmation before it can be accepted as true.

CINCINNATI GROUP.

By the term Cincinnati group we now distinguish the rocks which were designated by the former Geological Board as the *Blue limestone series*. The new name was first applied to them by Messrs. Meek and Worthen of the Illinois geological survey, and was intended to be the equivalent of the "Hudson group" (which includes Utica and Hudson rocks) of New York. The reasons given for the substitution of the name now used are, first; that the term Hudson group is a misnomer, as the so called Hudson rocks of New York do not reach to the Hudson river; those which were supposed to be their representatives on the Hudson having been proven to be of different and more ancient date; second;

that the exposures of the upper portion of the Lower Silurian series are more full and satisfactory about Cincinnati than anywhere else in our country; and that they are there replete with beautifully preserved and characteristic fossils which are distributed from this point to all quarters of the globe and make it a widely-known and typical locality. I am compelled, however, to modify in a slight degree the limits assigned to the Cincinnati group by Messrs. Meek and Worthen, from the impossibility of drawing any line through the Blue limestone series which will leave the equivalents of the Utica and Hudson shales above; of the Trenton limestone below. As will be seen by reference to the table of fossils on another page, we have in the Cincinnati group a hopeless and inextricable confusion of Hudson and Trenton species; so that if any division be made to represent these two periods, it must be a conventional and arbitrary one, such as has no existence in nature.

There are other reasons, also, as it seems to me, why the "Cincinnati group" should not be made the strict equivalent of the "Hudson group" of New York. These are, first; that the Hudson group *does* reach the banks of the Hudson, and although certain other rocks found on the Hudson river were once erroneously considered identical with these, that is not a sufficient reason for dropping the name. Second, if made co-extensive with the "Hudson group"—i. e. limited to the equivalents of the Hudson and Utica shales—the "Cincinnati group" would be the exact equivalent of the "rocks of the Hudson period," of Dana, and the "Nashville group" of Safford.

Since, therefore, the Blue limestone series of Cincinnati is *not* the exact equivalent of any group before named; is a homogeneous and indivisible whole, characterized by fossils of Trenton, Utica and Hudson age; and lastly, because the valley of the Ohio affords the best and best known exposures of the rocks of this great and indivisible era in the physical and life history of the continent, I feel constrained to accept the name bestowed by Messrs. Meek and Worthen, but to so far extend it as to include our representatives of the Trenton limestone as well as of the Utica and Hudson shales. Some of the palaeontological facts which compel this course, are given in the following table, where the vertical range of the most characteristic fossils of the Cincinnati group is compared with their stations in the Lower Silurian limestones of Canada, New York and Tennessee.

The abbreviations used in the table are to be translated as follows: Ch. Chazy; B. r. Blackriver; T. Trenton; U. Utica; H. Hudson; N. Nashville; C. Cincinnati group, station undetermined. The figures in the right hand column express the vertical range, in feet above low water—in the Cincinnati group of the fossils specified, as reported by Prof. Orton.

Table of Comparative stations of Cincinnati group fossils, in Canada, New York, Tennessee and Ohio.

	Canada.	New York.	Tennessee.	Ohio.
Stellipora antheloidea..................Hall		T.	N.	300–700
Tetradium fibratum................Safford	T. &. H.		T. & N.	650–800
Stenopora fibrosa ....Goldf.	Through.	Through.	Through.	Through.
S. petropolitana.......................Pand.	Ch. H.	Through.	T. & N.	300–450
Columnaria alveolata..............Goldf.	B. r.	B. r.	T.	C.
Petraia corniculum......................Hall	T. & H.	T.	T.	650–750
Favistella stellata.......................Hall	H.	H.	N.	750–800
Escharopora recta.......................Hall		T.		300–400
Protarea vetusta ....Hall	T.	T.		450–750
Heterocrinus heterodactylus........Hall		H.		50–300
Glyptocrinus decadactylus..........Hall		H.		300–400
Strophomena alternata...............Con.	Through.	Through.	Through.	Through.
S. tenuistriata............Sow.	T.	T. & H.	N.	450–750
S. planoconvexa. ....Hall		T.	N.	275–300
S. filitexta ....Hall	B. r. to H.	T.	T.	600–650
S. planumbona...........Hall	T. & H.	T.	N.	600–750
Orthis biforata..........................Eich.	T. & H.	T.	N.	Through.
O. testudinaria ....Dal	B. r. to H.	T. & H.	T. & N.	0–750
O. occidentalis.........................Hall	U.		N.	500–800
O. subquadrata ....Hall	T. & H.			625–800
O. retrorsa...........................Salter	T. & U.			475
O. plicatella............................Hall	B. r. to .U	T.		300–375
O. disparilis ....Con.	Ch. & B. r.		T.	375–500
O. pectinella...........................Hall	B. r. & T.	T.	N.	550–800
O. insculpta............................Hall	B. r. to U.	T.		550–700
Leptaena sericea.........................Sow.	T. & H.	T. & H.	T. & N.	0–750
Rhynchonella increbescens.........Hall	B. r. & T.	T. & H.	N.	600–750
Zyogospira modesta....................Hall	H.	U.	N.	0–800
Lingula quadrata ....Eich.	T. & H.	T.		0–750
Avicula demissa.........................Con.	H.	H.	N.	C.
Ambonychia radiata....................Hall	T. & H.	H.	N.	0–800
Cyrtodonta obtusa ....Hall	B. r. & T.	T.	N.	C.
Modiolopsis modiolaris..............Con.	H.	H.	N.	0–400
Orthonota contracta....................Hall	H.	H.		C.
O. pholadis ....Con.	H.	H.		C.
Cyclonema bilix.........................Con.	T. & H.	H.	N.	Through.
Pleurotomaria subconica.............Hall	B. r. to H.	T. & H.	T.	C.
Murchisonia gracilis ....Hall	B. r. to H.	H.	N. & T.	C.
M. bicincta.....................Hall	B. r. to T.	T.	T. & N.	C.
M. bellicincta...................Hall	B. r. & T.	T.		C.
Cyrtolites ornatus ....Con.	H.	H.	N.	C.
C. compressus..................Con.	B. r. & T.	T.	T.	C.
Bellerophon bilobatus..................Sow.	B. r. & T.	T.		C.
Conularia Trentonensis................Hall	T.	T.	N.	C.
Orthoceras proteiforme.................Hall	B. r. & T.	T. & U.		C.
O. crebriseptum...............Hall	H.	H.		C.
O. multicameratum ....Con.	Ch. to T.	T.	N.	C.
O. amplicameratum........Con.	B. r. & T.	T.	N.	C.
Oncoceras constrictum................Hall	B. r. & T.	T.	T.	C.
Calymene senaria........................Con.	T. & H.	T. & H.	T. & N.	C.
Lichas Trentonensis ....Con.	Ch. & B. r.	T.	N.	C.
Cheirurus pleurexanthemus......Green	T. & H.	T.	T.	C.
Trinucleus concentricus.............Eaton	T. & H.	T. & H.		C.
Asaphus gigas..........................DeKay	Ch. to H.	Ch. to T.	T. & N.	C.
A. megistos ....Locke	Ch. to H.	T.	T. & N.	C.

The area in which the rocks of the Cincinnati group underlie the surface, forms a triangle which includes the southwestern corner of the state; having its apex at Piqua, Miami county; one side reaching the Indiana line in Preble, the other the Ohio in Adams; the whole forming the northern extension of the "Blue grass" region in Kentucky, so frequently referred to in the analysis which has been given of the structure of the Cincinnati arch. The survey of this section of the State has been under the special charge of Prof. Edward Orton, who has made a most careful and thorough study of its geology. His description of the Cincinnati group will be found in another part of this volume. It is so full and accurate that I cannot do better than to refer those who are interested in the subject to his report for all details as to its structure and fossils. Prof. Orton divides the Cincinnati group, on lithological characters mainly, into three subdivisions, as follows; the first named being the highest.

1. The Lebanon beds.
2. The Cincinnati division—proper.
3. The Pt. Pleasant beds.

These have jointly a thickness of about 800 feet.

Since the base of the Blue limestone series is nowhere exposed, we cannot accurately determine its entire thickness. By Prof. Locke it was estimated to be about 1000 feet, and this, as we learn from the Columbus well, is not far from the truth.

It has been frequently stated that the lowest portions of this limestone series were exposed at Frankfort in Kentucky, and it has been estimated by David Christy, Esq., that the Kentucky river cuts 500 feet lower, geologically, than the Ohio. Maj. S. S. Lyon, who has written much more recently on the geology of Kentucky, states that all the "Kentucky river marble" series,—i. e. the thick-bedded limestones which border the valley of the Kentucky between Frankfort and Nicholasville—underlie the lowest strata exposed at Cincinnati. Further observations will be necessary, however, before we can determine with accuracy the relations which the Lower Silurian strata of the interior of Kentucky, bear to those of the Cincinnati section.

Maj. Lyon divides the Blue limestone series of Kentucky into three members, viz., the "Cincinnati group," the "Blue grass group" and the "Birdseye limestone group"; of which the aggregate thickness is estimated to be about 800 feet, nearly equally divided at the top of the "Birdseye limestone." The lowest member of the Kentucky series consists of somewhat thick-bedded and compact limestone strata which very generally exhibit the structure of the Birdseye limestone of New

York. This formation composes the picturesque cliffs of the Kentucky river below Nicholasville, and it is also exposed over a limited area east of Lexington. This latter point like Murfreesboro, Tennessee, seems to be the summit and centre of the Blue limestone dome, and the only place where the broad surface erosion has denuded the lowest group. Unfortunately the massive Kentucky river limestones are almost entirely destitute of fossils, so that up to the present time we lack the data necessary for determining satisfactorily whether or not we have in Kentucky the equivalent of the Birdseye of New York. The "Blue grass group" of Lyon is made to include those strata which immediately underlie the surface in the "Blue grass" region about Lexington. The limestones which compose this part of the series are thin bedded, but are more compact and contain less earthy matter than most of the rocks exposed at Cincinnati. Fossils are exceedingly abundant in these beds; more so, indeed, than at Cincinnati; but they are nearly all such as are found in the valley of the Ohio, and most of them range to the top of the Cincinnati group. At Frankfort, *Orthis testudinaria*, *Chaetetes lycoperdon* (*Stenopora petropolitana*), *Rhynchonella increbescens*, *Orthis lynx*, *Orthis occidentalis*, etc., are found immediately above the top of the, so called, Birdseye limestone group.

Maj. Lyon limits the Cincinnati group to the uppermost beds of the Blue limestone series; which in Kentucky are more argillaceous than those below. The fossils are, however, the same; and the distinction made by Lyon between the "Cincinnati" and the "Blue grass" beds, based mainly on lithological features, is scarcely so real and important as to deserve more than local recognition.

It is somewhat difficult to measure accurately the thickness of the strata which in Kentucky overlie the "Birdseye" limestone, and it is possible that Maj. Lyon's estimate is too low. If, however, his figures should prove to be accurate, and it should be ascertained that the interval between the Kentucky river beds and the Upper Silurian is only 400 to 500 feet, we shall hardly find in this interval the equivalents of all our 800 feet of Lebanon beds, Cincinnati division, and Pt. Pleasant beds, exposed about Cincinnati. One of two things is, therefore, probably true in this connection, viz.; either Lyon's "Blue grass" and "Cincinnati" beds are more than 400 feet thick, and represent all of the Cincinnati series—in which case the "Birdseye limestone" of the Kentucky river would be the equivalent of strata buried beneath the Ohio—or the "Kentucky river marble" is a local lithological phase of the lower beds of the Cincinnati section. Fossils will alone enable us to decide this question, and as yet we have found none in the valley of the Kentucky which throw

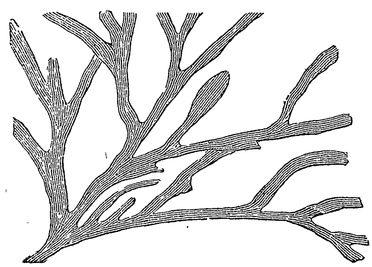
any light upon it. The Pt. Pleasant beds which form the base of the Ohio river section are considerably massive and somewhat resemble those exposed at Frankfort, but their fossils are not essentially different from those of the overlying strata; so that it is certain that down to the lowest layers exposed in the Ohio valley the Cincinnati group is essentially one formation.

It has been shown on preceding pages that the fauna of the Cincinnati group is composed of a mingling of Chazy, Black river, Trenton, Utica and Hudson fossils, and that these are so blended as to make it impossible to draw, on paleontological grounds, any line of separation in the group. The facts cited will probably be accepted as proof that the Cincinnati group represents at least a portion of the Trenton series of New York as well as the Hudson and Utica shales. It should be remembered, however, that the view we now have of the base of the Blue limestone series is very imperfect, and it is possible—though in my judgment not probable—that we may yet discover below all the beds exposed in the valley of the Ohio, strata which represent the Lower Trenton, with equivalents of one or all of the underlying limestones, the Birdseye, Black river and Chazy.

Fossils of the Cincinnati Group.

PLANTS. Figs. 1, 2.

1.



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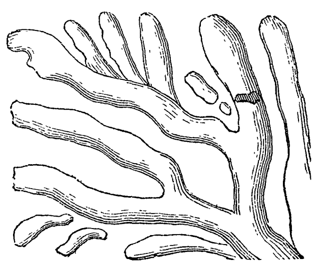


Fig. 1. *Buthotrephis gracilis*, Hall.

" 2. *B. succulosus*, Hall.

The fossils of the Cincinnati group are in some localities and strata so abundant as to make up a large part of the mass. They are often very beautifully preserved, and form a long list of genera and species, many of which will be found figured and described in the report of Mr. F. B. Meek which forms part of this volume. For the benefit of those who have not access to books on paleontology I also give herewith figures of some of the most common yet characteristic fossils of the Cincinnati

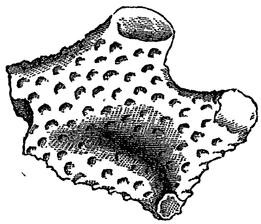
group; such as will be probably included in any collection made in the Blue limestone area, and yet such as could not be identified from any figures and descriptions given elsewhere in this report.*

Fossils of the Cincinnati Group.

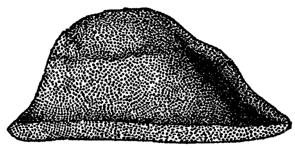
CORALS. Figs. 3, 4, 5.

3.

4.



5.



Figs. 3, 4. *Stenopora fibrosa*, Goldfus.
" 5. *S. petropolitana*, Pander.

In Mr. Meek's contribution to this volume many species of fossils from the Cincinnati group will be found described for the first time. For this fine array of new and beautiful material we are largely indebted to some of the citizens of Cincinnati who have made the fossils of the Blue limestone objects of special study for many years, and have formed collections which, in the number of species they contain, and their beauty of preservation, are probably unequalled among all the other collections of paleozoic fossils which exist in the world. These have, with great liberality, been not only thrown open to our inspection, but all their rich stores have been placed at our disposal for study and description. To Mr. C. B. Dyer, Mr. U. P. James and Mr. S. A. Miller we are under special obligations for favors of this kind.

* For the woodcuts which illustrate this chapter I am indebted to the courtesy of Mr. E. Billings and Prof. J. D. Dana, who, when it was found impossible to procure good original figures, have kindly permitted me the use of some of the cuts which illustrate the "Manual of Geology" and the "Report on the Paleontology of Canada."

Fossils of the Cincinnati Group.

BRACHIOPODS. Figs. 6–11.

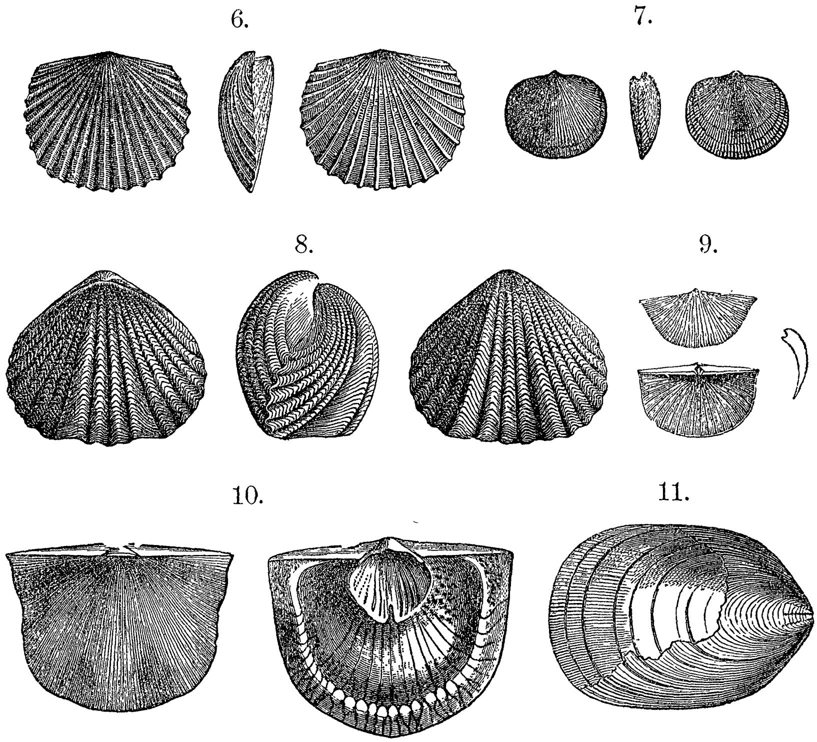


Fig. 6. *Orthis pectinella*, Conrad.
" 7. *O. testudinaria*, Dalman.
" 8. *Rhynchonella increbescens*, Hall.
" 9. *Leptaena sericea*, Sowerby.
" 10. *Strophomena filitexta*, Hall.
" 11. *Lingula quadrata*, Eichwald.

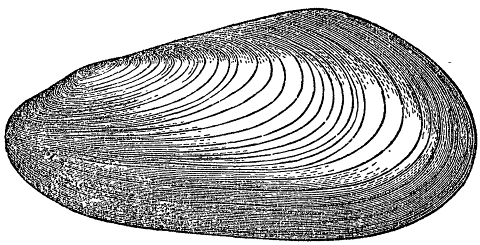
It will be seen by reviewing the fauna of the Cincinnati group, that all the lower orders of animal life were represented in the sea from which these limestones were precipitated, and that this sea was teeming with members of all the great invertebrate groups, crustaceans, mollusks, radiates and protozoans. Not a particle of any vertebrate organism has, however, as yet been found in these strata, and we may be quite sure, from the fidelity with which the remains of millions of delicate invertebrates have been preserved, that if any fishes had inhabited the old

Silurian ocean we should have found abundant evidence of the fact. We must, therefore, conclude that all the fauna of the Cincinnati group belongs to an age in which no vertebrate animals existed on the globe; when gigantic cuttle fishes—of which the *Orthocerata* were internal shells—were the monarchs of the animal kingdom in virtue of their power and prowess; and the trilobites were the most highly organized and stood at the summit of the scale of being. Few members of the protozoa have been found about Cincinnati, but the southern extension of the strata exposed in the valley of the Ohio have yielded, in Kentucky, some large and remarkable fossil sponges (*Brachiospongia*) and numerous *Foraminifera* (*Receptaculites*).

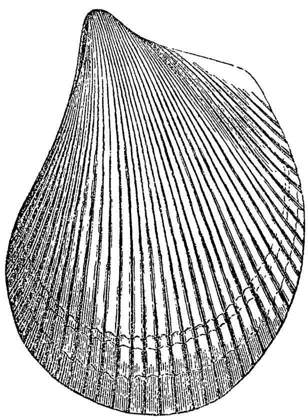
Fossils of the Cincinnati Group.

CONCHIFERS. Figs. 12–14.

12.



13.



14.

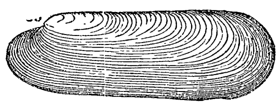


Fig. 12. *Modiolopsis modiolaris*, Conrad.
" 13. *Ambonychia radiata*, Hall.
" 14. *Orthonota parallela*, Hall.

The most interesting of the fossils of the Cincinnati group are trilobites and of one species, (*Asaphus megistos*) fragments are exceedingly abundant, and such as indicate a gigantic size. No perfect specimen of the largest dimensions has been procured, but very considerable portions of heads and bodies have been found which must have belonged to individuals nearly two feet in length. Extensive surfaces of the limestone layers are sometimes covered with fragments of the shells of these crustaceans, and the broken and dismembered condition of these remains has been productive of great surprise and disappointment on the part of collectors, as a thousand pieces may be obtained before an entire individual is met with. This is probably due to the fact that, like its living analogue, the horse shoe crab, the trilobite cast its shell at frequent intervals during its most rapid growth, so that a single individual in all its life, may have contributed hundreds and even thousands of fragments to these accumulations of *exuviae* which covered the sea bottom.

Fossils of the Cincinnati Group.

GASTEROPODS. Figs. 15–17.

15. 16. 17.

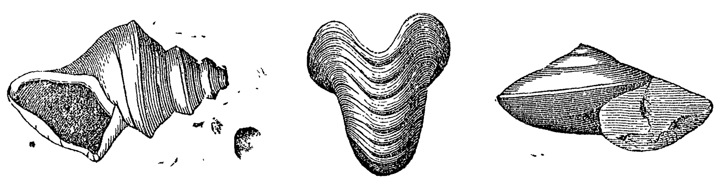


Fig. 15. *Murchisonia bicincta*, Hall.
" 16. *Bellerophon bilobatus*, Sowerby.
" 17. *Pleurotomaria Americana*, Billings.

A complete list of the fossils of the Cincinnati group found in Ohio will be given in the Paleontological report of Mr. Meek.

Fossils of the Cincinnati Group.

CRUSTACEA. Figs. 18–22.

18. 19. 20. 21.

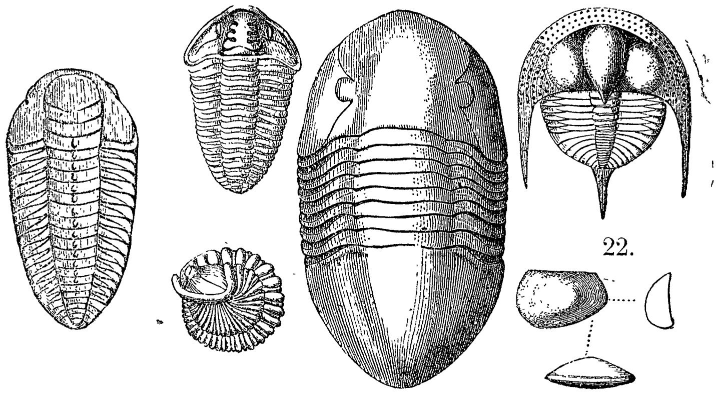


Fig. 18. *Triarthrus Beckii*, Green.
" 19 *Calymene senaria*, Conrad.
" 20. *Asaphus gigas*, DeKay.
" 21. *Trinucleus concentricus*, Eaton.
" 22. *Leperditia fabulites*, Conrad.

MEDINA AND CLINTON GROUPS.

In southwestern Ohio, about Dayton, Yellow Springs, &c., the rocks of the Cincinnati group are overlaid by a few feet—10 to 20—of red, blue and mottled calcareous clay or shale—sometimes a yellow indurated marl—upon which the Clinton limestone rests. These strata contain no fossils, so that it is impossible to say whether they represent portions of the Clinton or of the Medina group; but the Clinton shales of New York and Pennsylvania, if they have followed the law which has controlled the deposition of all the other mechanical sediments of the series, should have disappeared before reaching a point so far west; whereas the Medina sandstone, being much coarser, should have a greater westward extension. Hence it seems to me probable that these mottled clays or marls, interposed between the Clinton and Cincinnati limestones, represent the Medina of New York.

In the northern part of the state, about Toledo, and at the mouth of the Vermillion, wells bored for oil have reached red shales and sandstones, holding the precise position, and corresponding better in thick-

ness, texture and color with the Medina sandstone of New York than do the strata we have doubtfully referred to the Medina in south-western Ohio. In the Vermillion well, the red stratum underlying the Clinton was found to be thicker and more sandy than at Toledo and Waterville; showing that,—following the general law,—this formation becomes thicker and coarser toward the north-east.

In my notes on the State House well at Columbus I have referred to the red shales passed through at the horizon of the Medina. From what we learn by the register and borings of the well we may infer that the Medina in the central part of the state is thicker than near Cincinnati, but less red and less sandy than on the Lake shore.

The Clinton group has now been fully identified, and, thanks to the efforts of Prof. Orton, accurately defined in Ohio. The first intimation received of its presence among the rocks of the Mississippi valley was given by Prof. Hall, in the notes on his journey of 1841, when his attention was called by Prof. Locke to the strata immediately overlying the Blue limestone series at Madison, Ind.; strata which he suggested might represent the Clinton of New York. No Clinton fossils were obtained, however, by Prof. Hall, and no real proof of the presence of this formation in Ohio was gathered previous to the organization of the present Geological Corps. Almost immediately, after beginning his survey of the south-western part of the state, Prof. Orton obtained positive evidence that the Clinton forms the basal portion of the "Cliff limestone" of Dr. Locke. He has since traced it throughout all its long line of outcrop and studied its structure with very interesting results; some of which have been alluded to. If, as has been suggested on a preceding page, the red and mottled clays which rest immediately on the Cincinnati group, form the westward extension of the Medina, then our chief representative of the Clinton group, is a cream colored, sometimes salmon colored limestone, from 10 to 50 feet in thickness, which lies between the Niagara and the Medina. The outcrop of this limestone follows a tortuous line from the Ohio in Adams county around the Lower Silurian area, to the Indiana line in Preble; and several of the islands formed by erosion in the apex of the Blue limestone triangle near Dayton are capped by this rock.

In the description given of the structure of the Cincinnati axis I have alluded to the interesting discovery made by Prof. Orton, that in Adams and Highland counties the Clinton contains a bed of conglomerate composed of rolled pebbles apparently of the underlying Cincinnati group; with beach-worn Clinton and Cincinnati fossils. This seems to prove

that before the deposition of the Clinton, the Cincinnati rocks were consolidated and elevated above the sea level.

Prof. Orton has also found in Adams county a thin sheet of iron ore which undoubtedly represents the "fossil ore" which runs through all the northern and eastern outcrops of the Clinton group.

The fossils of the Clinton are quite numerous and a number of those collected by Prof. Orton are new to science. They will be found more fully described in his report and that of Mr. Meek. In New York the most conspicuous fossil of this group is *Pentamerus oblongus*, of which a figure is given below. This is a widely disseminated fossil, as it is found on both sides of the Atlantic and in various parts of our own country. In southern Ohio, it occurs in the overlying beds of the Niagara, and at Yellow Springs is found of greater size and more perfectly preserved than in any other locality known.

Fossils of the Clinton Group.

Figs. 23–27.

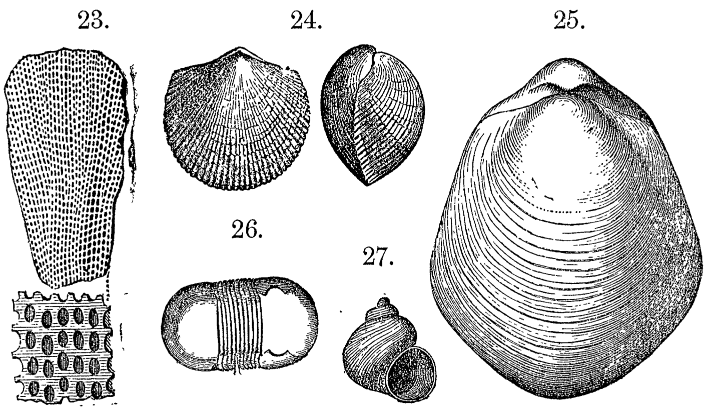


Fig. 23. *Fenestella prisca*, Lonsdale.
" 24. *Atrypa reticularis*, Linnaeus.
" 25. *Pentamerus oblongus*, Sowerby.
" 26. *Illænus Barriensis*, Murchison.
" 27. *Cyclonema cancellata*, Hall.

NIAGARA GROUP.

This is a wide-spread formation, and one that marks an interval of general marine conditions over a large part of the valley of the Mississippi. It underlies all the geological series exposed in Ohio, except

within the limited area already described, where the older rocks come to the surface. Around this area it forms a belt of outcrop, parallel with that of the Clinton, but broader, as the formation is thicker. The Niagara limestone also forms the crown of the Cincinnati anticlinal from Dayton to the Lake, with the exception of a narrow space north of Bellefontaine where the next succeeding formation stretches over the arch. In the counties of Hardin, Hancock, Wood, Wyandot, Seneca, Sandusky and Ottawa, the Niagara comes to the surface in an irregular belt which near the Lake becomes double; showing a double fold in the Cincinnati arch.

In the northern part of the state the best exposures of the Niagara are at Genoa, Elmore and Washington, on the Lake Shore railroad, where it is extensively quarried and burned for lime. In all this region only the upper part of the Niagara is seen, the equivalent of the Guelph limestone of Canada, formerly and erroneously considered a part of the Salina group. This portion of the formation is a rough, cellular, cream-colored magnesian limestone, sometimes mistaken for sandstone, yet being nearly a typical dolomite in composition, and producing, when calcined, excellent quicklime. The cells and cavities which are so characteristic of this rock are usually produced through the removal, by solution, of the shells, of which it once contained great numbers; hence all its fossils are represented by casts only.

Among the fossils of the Niagara group, which occur most abundantly in Northern Ohio, may be mentioned *Megalomus Canadensis*, *Tremanotus alpheus*, *Pleurotomaria solarioides*, *Murchisonia macrospira*, *Trimerella Ohioensis*, *Pentamerus occidentalis*, *Cypricardites? quadrilatera*, *Favosites Niagarensis*, *Obolus Conradi*, etc.

In the southwestern portion of the state, the Niagara group is cut through, not only over the Blue limestone area, but by the erosion of many of the valleys which lead into it; so that good sections of the formation are afforded at many points. Of these the best are near Hillsboro in Highland county, and one of the most complete, furnished me by Prof. Orton, is given below, as an illustration of the structure of the Niagara group in this portion of the state.

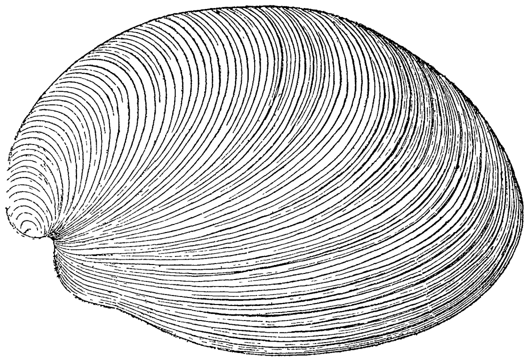
Section of Niagara rocks at Hillsboro.

		FEET.
1.	Hillsboro sandstone	36
2.	Cedarville, or Pentamerus limestone	20
3.	Upper, or Springfield Cliff	45
4.	Lower, or West Union Cliff	45
5.	Niagara shales	60
6.	Dayton limestone	5

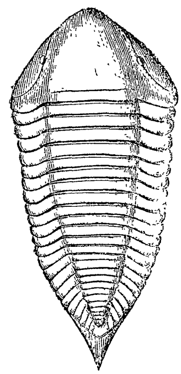
For a detailed description of the strata which form the preceding section, the reader is referred to the report of Prof. Orton which forms part of the Report of Progress for 1870.

Fossils of the Niagara Group.

28.



29.



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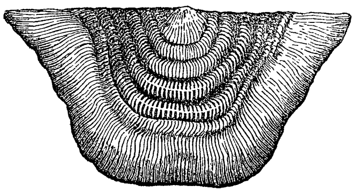

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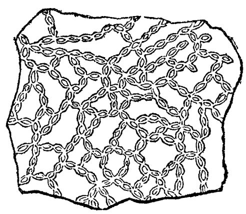


Fig. 28. *Megalomus Canadensis*, Hall.
" 29. *Homalonotus delphinocephalus*, Green.
" 30. *Strophomena rhomboidalis*, Wahlenberg.
" 31. *Halysites catenulatus*, Linnæus.

The fossils of the Niagara in southwestern Ohio are exceedingly numerous, and some of them of peculiar interest. Most of the species collected on the Survey, are such as have been before obtained from the Niagara group, in New York, Canada, or the north-western states. Quite a number of species, have, however, proved new to science, and these will be found described in the report of Mr. Meek. The upper limestone of the Hillsboro section is evidently the equivalent of that exposed at Genoa, Elmore, &c., and, like that, represents the Guelph division of the Niagara. It contains nearly the same fossils at Hillsboro as at Genoa, but *Pentamerus oblongus* is much more abundant here than at the north; as in some localities about Hillsboro, it makes up the larger part of the mass of limestone which contains it. The following

ist includes the most characteristic fossils obtained from the southern exposures of the Niagara:

Favosites Niagarensis, Hall.
Halysites catenulatus, Linn.
Caryocrinus ornatus, Say.
Eucalyptocrinus cornutus, Hall.
Holocystites cylindricus, Hall.
Gomphocystites glans, Hall.
Trimerella Ohioensis, Meek.
T. grandis, Billings.
Obolus Conradi, Hall.
Pentamerus oblongus, Sow.
Atrypa reticularis, Linn.
Strophomena rhomboidalis, Wahl.
Pleurotomaria Halei? Hall.
Murchisonia macrospira, Billings.
M. Laphami, Hall.
Platyceras Niagarense, Hall.
Megalomus Canadensis, Hall.
Trochoceras Desplainense, McC.
Orthoceras abnorme, Hall.
Calymene Niagarensis, Hall.

The economic value of the Niagara is perhaps greater than that of any other Ohio limestone group. In southwestern Ohio the lowest stratum of the Niagara is, over quite a large area, a sheet of homogeneous, light blue limestone, which,—known as the Dayton stone,—is one of the best and most highly esteemed building stones in the state.

The middle and upper beds of the Niagara, though rarely furnishing a desirable stone for architectural purposes, supply a larger amount of the quicklime used in the state than is derived from any other source. The lime obtained from the Niagara limestone at Yellow Springs and Springfield, has nearly excluded all other kinds from the Cincinnati market, and the preference given to this lime—which causes it to be brought a distance of many miles to a city surrounded by hills composed of limestone—illustrates well the fallacy of the common judgment, according to which the value of a quicklime is accurately measured by the quantity of carbonate of lime contained in the stone from which it is made. For example: the Blue limestone at Cincinnati contains from 90 to 92 per cent. of carbonate of lime, while the Springfield stone contains nearly as much magnesia as lime.

The following analyses show the composition of the limestone burned for quicklime, at Yellow Springs (1), Hillsboro (2), and Springfield (3).

	1.	2.	3.
Carbonate of lime	54.75	54.25	50.90
Carbonate of magnesia	42.23	43.23	39.77
Silicates of lime and magnesia	....	....	7.07
Silica	0.40	0.40	1.19
Alumina and iron	2.00	1.80	0.70
Total	99.38	99.68	99.63

In the northern part of the state the lime made from the Niagara at Genoa, Fostoria, &c., has a reputation not inferior to that from Springfield. Two analyses, given below, from Fostoria (1) and Carey (2), will show that the upper beds of the Niagara have nearly the same composition, at localities remote from each other :

	1.	2.
Carbonate of Lime	55.40	54.20
Carbonate of magnesia	43.28	44.80
Silica	0.20	0.10
Alumina and iron	0.60	0.80
Total	99.48	99.90

It will be interesting to note in this connection the variation in the quantity of lime and magnesia contained in the different limestones of the Silurian series. As has been mentioned, the limestones of the Cincinnati group contain from 90 to 92 per cent. of carbonate of lime, and only about 1 per cent. of carbonate of magnesia. The Clinton, in its different layers and localities, varies considerably in composition ; the carbonate of lime ranging from 84 to 95 per cent., the carbonate of magnesia from 3 to 13. The Dayton stone—base of the Niagara—is a very pure limestone, containing, according to Dr. Locke, about 92½ per cent. of carbonate of lime and 1 per cent. of carbonate of magnesia. The middle and upper layers of the Niagara are almost always what may be called typical dolomites ; containing over 40 per cent. of carbonate of magnesia and a little over 50 per cent. of carbonate of lime. The prevailing composition of the Waterlime is almost identical with that of the Niagara, i. e. it contains nearly as much magnesia as lime. Few analyses of the Corniferous (Devonian) have yet been made, but these indicate a much smaller amount of magnesia ; probably not exceeding from 20 to 25 per cent.

SALINA GROUP.

This formation has received the name it bears on account of the large quantity of salt it contains, either in solution or as rock salt. The salt wells of Salina, N. Y., and those of Goderich, Canada, all draw their brine from strata of this age ; and at Goderich a thick stratum of rock salt was penetrated in boring.

In a preceding chapter I have given my reasons for believing that during the Salina period—as subsequently in the Triassic—the preexistent sea was shallowed and partially withdrawn from the land so as

to leave large basins where the salt water was gradually evaporated and its solid contents precipitated to form peculiar sediments on the bottom; in certain localities clay strongly impregnated with salts, in others, sheets of rock salt and of the mineral so constantly associated with it in sea water, gypsum.

In Ohio, the only representatives of the Salina group are certain earthy and gypsiferous limestones found lying between the Waterlime and the Niagara on the Lake shore, chiefly in Ottawa County. These strata hold precisely the geological position of the Onondaga Salt group of New York, but the formation is much thinner in Ohio and more uniform in color and mineral character. Going south from the Lake shore, the interval between the Niagara and Waterlime rapidly diminishes, until, in the central part of the state they are in absolute contact; the Salina being last seen at Moore's Mill, in Sandusky county, where it is represented by about 1 foot of soft, bluish, shaly limestone. There is little doubt, therefore, that we have in this section of the state, the edge of the great sheet of Salina rocks which in central and western New York have a thickness of nearly 1000 feet; *and that the Cincinnati axis here formed the western margin of the basin in which they were deposited.*

The best exposures of the Salina in Ohio are found on the peninsula north of Sandusky Bay and on Put-in-Bay island. At South point on this island the Waterlime group is underlaid by an impure, massive limestone of which a thickness of about 10 feet is exposed above the level of the Lake. This stratum is blue when freshly broken, but weathers to a chocolate color by the oxidation of its iron. It exfoliates in such a way as to give the appearance of a concretionary structure. This is due, however, to the decomposition of the rock which takes place in the joints as well as on the external surface. No fossils have been detected in the limestone at this locality. Its composition, according to the analysis of Dr. H. Endemann, is as follows:

Carbonate of lime	31.536
Carbonate of magnesia	27.760
Silica	29.450
Alumina and oxide of iron	9.250
Total	97.966

In the bottom of the Lake, near the locality mentioned, a stratum of gypsum is exposed, as it is often drawn up on the anchors of vessels, On the opposite shore of the peninsula, the cliffs at Ottawa point show the Salina below the Waterlime, precisely as on Put-in-Bay island. On the south side of the peninsula, the formation is more deeply penetrated

and at the "Plaster beds" has been extensively quarried for the gypsum it contains. The section exposed at this point is as follows:

		FEET.
1.	Drift clay	10—15
2.	White crystallized gypsum	0—4
3.	Shaly limestone	1
4.	Snowy gypsum	4
5.	Shaly limestone	1.3
6.	Snowy gypsum, to the bottom of the quarry	6

The surface of the upper gypsum bed is here deeply eroded; the inequalities being filled in with Drift clay. In some instances the stratum of gypsum is quite cut through so that in section it seems to form masses surrounded by the clay. All this irregularity is, however, the result of surface erosion, and the upper gypsum bed was once, like the lower ones, a uniform stratum 5 feet or more in thickness.

From the section given above it will be seen that the gypsum in this locality is accurately stratified and lies in regular beds, separated by thin layers of limestone. There are here no examples of the accumulation of gypsum in large concretionary masses, such as are reported to occur in the Onondaga Salt group of New York; and all the features of the deposit indicate—and may be said to prove—that the gypsum was precipitated in continuous sheets, and has not resulted from any change produced in carbonate of lime by acid waters, as claimed, I suspect without good reason, for the gypsum of New York. Small concretions of gypsum are common enough in the Salina strata at the old plaster beds near the locality which has been described, but these are entirely isolated and are undoubtedly concretionary in character; i. e. they have been formed by the withdrawal of the gypsum from its dissemination in the surrounding earthy limestone, and its concentration around a common centre of attraction. A similar process, operating on a larger scale, would produce the large, isolated masses of gypsum found in New York; and such, in my judgment, is the true theory of their origin. I can at least say in regard to all the great deposits of gypsum which have come under my observation that the evidence is conclusive to my mind that they are wide spread sheets of sulphate of lime precipitated from solution in sea water, and are not the result of any local action of acid springs. The Triassic gypsums of the far west, those of the Carboniferous series in Arizona and Michigan, and those of the Salina in Ohio, are certainly of this character.

The circumstances under which the Salina rocks were deposited would seem to have been very unfavorable to animal or plant life; and as a

consequence these strata are peculiarly barren of fossils. Up to the present time they have yielded not a trace of organic remains in Ohio.

WATERLIME GROUP.

In the state of New York the Salina is overlaid by a series of strata which have been united under the name of the Lower Helderberg group. These, in ascending order, are, the "Waterlime," the "Lower Pentamerus limestone," the "Delthyris shaly limestone," the "Encrinal limestone" and the "Upper Pentamerus limestone;" the latter forming the summit of the Silurian system. In the Helderberg mountains these strata contain a large number of fossils, some of which are peculiar to each stratum, and serve for its identification wherever found. In Ohio we have as yet failed to recognize any other member of this important series of rocks than the lowest—the Waterlime—and the identification of this formation was accomplished only after the organization of the present Geological Corps.

In the Helderberg mountains, the Lower Devonian rocks exist in great force, and to distinguish these from the Upper Silurian strata to which I have referred, the New York geologists called one group the Lower, and the other the Upper Helderberg. Since these groups belong to different geological systems and the names applied to them render it difficult to distinguish them as clearly as is desirable, I have taken the liberty to limit the name Helderberg to the Upper Silurian strata; designating the "Upper Helderberg" limestones as the Corniferous group, inasmuch as they are only locally distinguishable from the Corniferous limestone, are the product of one life period and of one epoch in the round of physical changes which took place in the Devonian age. Of the Helderberg strata, the Waterlime is by far the most wide-spread and important, and it is even doubtful whether any other member of the formation extends westward beyond the limits of the state of New York. In the vicinity of Buffalo, the Waterlime is distinctly recognizable, but is apparently the only representative of the group. It here has the character of an argillaceous limestone extensively used for the manufacture of hydraulic lime. The thickness of the Waterlime at Buffalo is apparently as great as in Schoharie county, and being a limestone it might be expected to extend farther westward, but it had not been recognized beyond the limits of New York previous to 1869. At that time in making an examination of the islands in Lake Erie, I discovered that while the eastern islands, (Kelley's and Middle Island), and Marble Head—the extremity of the peninsula—were composed of the Cornif-

erous limestone, containing an abundance of the characteristic fossils of that formation, the more westerly islands and the western portion of the peninsula were formed of several strata of limestone very unlike the Corniferous, and almost destitute of fossils. Of this series of beds the most conspicuous member is a peculiar gray brecciated limestone which forms all the islands west of those I have mentioned. This limestone is in most localities entirely without fossils, and it was a long time before any satisfactory evidence of its age could be obtained. It was found, however, at certain points to contain great numbers of minute bivalve crustacea, which resembled *Leperditia alta*; a characteristic fossil of the Waterlime in New York. This led to a careful search for further proof of the age of the rock which contained it, and this search resulted in the discovery of *Spirifer plicatus*; subsequently of *Avicula rugosa*, finally of *Eurypterus remipes*; the latter found in considerable numbers at Peachpoint opposite Gibraltar.

The section of the Waterlime strata exposed on Put-in-Bay island is as follows:

		FEET.
1.	Gray, often brecciated, massive limestone	40
2.	Thin-bedded, cream-colored limestone	3—7
3.	Coarse, brown, brecciated limestone similar to No. 1	10
4.	Blue or gray flaggy Waterlime	12
5.	Blue, earthy limestone of the Salina group, to the Lake	10

It is not easy to determine what is the entire thickness of this formation on the islands, as its junction with the Corniferous is nowhere seen. I am led to believe, however, that it is about 100 feet.

Fossils of the Waterlime.

Figs. 32 and 33.

32.

33.

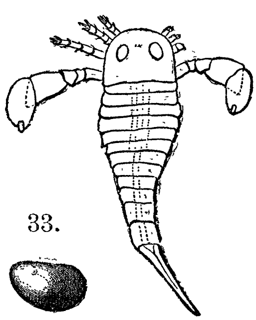


Fig. 32. *Eurypterus remipes*, DeKay.
" 33. *Leperditia alta*, Conrad.

Since our first identification of the Waterlime, we have traced it over a very large area within this state and have learned to recognize it almost at a glance by its prevailing lithological characters. We have also obtained its characteristic fossils from hundreds of localities. The result of our investigations has been to show that the Waterlime—judged by the area it occupies with its outcrops—is, in Ohio, the most important of all the Silurian strata. It underlies a broad belt of country on either side of the Cincinnati axis, from the Lake shore to Hardin county. There the two belts coalesce and the Waterlime stretches entirely over the arch, forming the surface rocks for nearly a hundred miles east and west. Further south the margin of the Waterlime sweeps around the Blue limestone area, exterior to and parallel with that of the Niagara.

South of the National road and east of the anticlinal axis, the Waterlime forms a constantly narrowing belt which passes through the counties of Madison, Fayette, Highland and Adams, to the Ohio. In parts of Highland and Adams, it forms a feather edge on the flanks of the Cincinnati arch; beyond which the Huron shale rests directly on the Niagara. *This shows that the sea in which the Waterlime was deposited reached but part way up the slope of the old Silurian island.*

The best exposures of the Waterlime in the northern part of the state, are on the islands of Lake Erie, but it is visible at a great number of localities south of the Lake shore, as at Fremont, Lima, Ottawa, Kenton, &c.; in all of which places it is extensively burned for quicklime.

In the southern part of the state the Waterlime is perhaps best shown near Greenfield, in the north east corner of Highland county. Here it is nearly 100 feet thick, but rapidly runs out westward. Most of the formation at Greenfield consists of brown or gray, somewhat earthy limestone, which forms a great number of relatively thin layers, much used for flagging. The only fossils found here are *Leperditia*, but south of Greenfield, on Buckskin creek, and north, on Sugar creek, the upper portion of the formation is highly fossiliferous, and contains several species which are apparently new.

In northern Ohio, where the Waterlime is very massive, it is remarkably cavernous; more so, indeed, than any limestone in the series. This is doubtless due to the fact that it is more soluble in atmospheric water than the associated limestones, as in the same vicinity, where the Corniferous is a close, solid and impervious rock, and the Niagara, though cellular, contains no large cavities, the Waterlime is honey-combed by caves and subterranean water-courses. This is well shown on Put-in-Bay island, where a number of caves are known to exist at the present time, and the places of many others are marked by peculiar sink-holes

or basin-like depressions of the surface formed by the falling in of the roofs. Castalia springs, in Erie county, apparently form the outlet of one of the subterranean rivers which traverse the Waterlime.

The economic value of the Waterlime depends mainly upon its adaptation to the manufacture of quicklime and hydraulic cement. In some localities it supplies a good building stone, but, for this purpose, it is, generally, much inferior to the Corniferous limestone. It is largely used for the manufacture of lime, and in a great number of localities furnishes that which is of excellent quality. The Fremont lime may be considered as typical of that produced from the Waterlime. As might be inferred from the composition of the rock it is very similar to that made from the Niagara; it slacks less rapidly than the Corniferous lime, and works a little more slowly, but forms a mortar of snowy whiteness and that which is especially adapted to outside work, as the large amount of magnesia it contains seems to impart to it hydraulic properties, while yet the quantities of silica and alumina it contains are small.

Certain strata of the Waterlime formation are much better adapted to the manufacture of lime than others, and these are the massive, somewhat brecciated beds which have been referred to in the notes given on the Waterlime of Put-in-Bay island. Some of the flaggy layers which underlie these and contain a larger amount of earthy matter, slack imperfectly when burned, but make excellent hydraulic cement. Unfortunately only part of these layers have this property, and the difficulty of separating the hydraulic limestone from that which is interstratified with it, and has no value, has hitherto rendered the efforts to manufacture cement from this formation, but partially successful.

The different strata of the Waterlime group vary considerably in chemical composition, but are all highly magnesian. I give below four analyses—the strata being numbered in descending order—of the massive beds, and four of the flaggy layers, from the Waterlime of Put-in-Bay island:

Analyses of the massive beds of the Waterlime group, Put-in-Bay Island, made by Prof E. W. Root.

	1.	2.	3.	4.
Carbonate of lime	54.03	55.40	54.23	63.37
Carbonate of magnesia	41.64	42.37	44.98	32.57
Alumina and oxide of iron	0.40	0.30	0.56	0.40
Insoluble residue	0.30	0.29	0.74	0.33
Loss by ignition	1.81	1.15	0.35	0.68
Total	98.18	99.51	100.86	97.36

Analyses of hydraulic layers of Waterlime from South point, Put-in-Bay, by Dr. H. Endemann.

	5.	6.	7.	8.
Carbonate of lime	51.43	49.11	51.28	42.95
Carbonate of magnesia	40.24	36.87	39.65	39.79
Silica	3.85	10.05	7.80	13.30
Alumina and iron	3.85	3.65	2.75	3.55
Total	99.37	99.68	101.48	99.59

Analyses of the limestone used for the manufacture of lime at Fremont; by Dr. H. Endemann.

	1.	2.	3.
Carbonate of lime	47.45	54.50	39.58
Carbonate of magnesia	51.18	45.13	58.74
Silica	0.43	0.22	0.32
Alumina and iron	0.68	0.42	0.46
Total	99.74	100.27	99.10

In order to correct the popular error that magnesian limestones do not afford good quicklime, I add below two analyses of the Sing Sing dolomite which furnishes the most highly esteemed and highest-priced lime used in New York and the cities on the Hudson; the first made by Dr. Lewis C. Beck, the second by Charles K. Gracie, E. M.

	1.	2.
Carbonate of lime	53.24	54.82
Carbonate of magnesia	45.89	44.13
Silica, alumina and iron	0.87	0.65
Total	100.00	99.60

By reference to the report of Prof. Orton, in our Report of Progress for 1869, pp. 152 and 153, it will be seen that the Niagara limestone, at Springfield, Yellow Springs and Hillsboro—from which the lime is made most highly esteemed in Cincinnati—has almost precisely the composition of the upper beds of the Waterlime on Put-in-Bay Island.

CHAPTER V.

DEVONIAN SYSTEM.

ORISKANY SANDSTONE.

The Devonian rocks of Ohio form a circle of deposits, which records an invasion of the land by the sea, and presents in its series of strata, a history of the successive stages of that invasion; first, the mechanical sediment of the Oriskany; then the Corniferous limestone, the deposit of the open ocean; then mixed mechanical and organic materials—the Hamilton, Huron and Erie shales,—the mechanical sediments finally predominating and indicating a return to land conditions over all the eastern portion of the continent.

As has been mentioned in the sketch given of the structure of the Cincinnati anticlinal, the sea of the Devonian age was bounded on the south-west by the islands which were formed by the higher portions of the axis. On the north, the Canadian highlands were part of a great continental area of which the shores were washed by the Corniferous sea. On the east, there was land in eastern New York, eastern Pennsylvania, and doubtless in Virginia; but over all the intermediate space a warm sea prevailed; even its northern margin being studded with coral reefs and islands, and its shores having a tropical vegetation.

In Ohio, the submergence which produced the Devonian strata, was marked by a deepening of the already existing Upper Silurian sea, rather than by the sinking of any considerable land area. We have, however, in the Oriskany sandstone, a record of such submergence; though all its most conspicuous effects were produced in the states east of Ohio. The Oriskany sandstone is in the east, as its name indicates, a coarse, mechanical sediment, and it contains a group of fossils peculiar to itself. These are chiefly mollusks, and, so far as known, not a fragment of a vertebrate of any kind has yet been discovered in the formation. In later geological periods, shore deposits like this almost always contained the remains of land plants, but none have yet been found in the Oriskany; which seems to prove that at least no abundant vegetation

covered the shore cut away by the waves. Yet in the succeeding period the islands and probably the continents washed by the sea of the Middle Devonian sustained a varied and beautiful flora.

In West Virginia, on the borders of Ohio, the Oriskany sandstone attained great thickness; and if we could penetrate the overlying strata in the centre of our coal basin, we should doubtlessly find this formation well represented there; but in the middle and western portions of the state where it comes to the surface, it is in many places entirely wanting, and no where attains a thickness of more than 10 feet. We have hitherto failed, also, to find any Oriskany fossils in Ohio, and it may even be questioned whether the formation can be fully identified here; but at the base of the Devonian series, under the Corniferous limestone, —sometimes interstratified with it,—we find, in numerous localities, a coarse saccharoidal sandstone which holds the precise position of the Oriskany, and incontestably marks the period of its deposition. This sandstone may be seen at West Liberty, in Logan county, in Scioto township, on the western line of Delaware; on the peninsula west of Marble Head in Ottawa; at Sylvania in Lucas; and in many other places. In these localities it is from three to ten feet in thickness; usually soft and white; and is often capable of being used in the manufacture of glass. Indeed a considerable quantity of stone was taken from this bed, at Sylvania, and transported to Pittsburgh, where it was successfully used in glass making.

By reference to the register of the State House well at Columbus, given on a preceding page, it will be seen that at the depth of 276 feet, at the base of the Corniferous limestone, a "very gritty rock" was passed through; a thickness of only two feet is assigned to it in the register, but it may have been a little thicker. This is unquestionably the same stratum which shows itself beneath the Corniferous limestone at so many localities where the base of that limestone is exposed; and it is a matter of some wonder that it was not found of greater thickness, as we might have expected it to increase considerably in force at a locality so far south and east of its known outcrops, and in a direction toward the massive beds of the Oriskany sandstone which are found in West Virginia.

In the western part of Delaware County, the base of the Corniferous limestone contains many rolled pebbles of the Helderberg limestone, forming a calcareous conglomerate, which has been referred to as marking a shore line and a break between the Upper Silurian and Devonian strata. This conglomerate holds the position of the Oriskany, and is not a sandstone simply because there was nothing on this old shore to make silicious sand of. It should probably, however, be considered an Oriskany conglomerate.

CORNIFEROUS LIMESTONE.

The members of the former Geological corps divided the rocks which underlie the western half of Ohio into two great limestone groups, the "Blue limestone series,"—now known asthe Cincinnati group,—and the "Cliff limestone," which, as more recent investigations have shown, includes representatives of the Clinton, Niagara, Waterlime, Corniferous, and, locally, of the Hamilton strata.

This series of limestones have, for the most part, a light brown or cream-colored tint; and united, as they are in some localities, in one great calcareous mass, with no considerable intervening stratum of different character, it is not surprising that they should have been grouped together under one name. This name was intended to be descriptive of the perpendicular escarpments or cliffs formed by a portion of the series on the banks of some of the tributaries of the Ohio. From the want of an accurate knowledge of paleontology it was impossible, a quarter of a century ago, to divide the "Cliff" into its constituent elements; and this has been done only since a careful study of its fossils has shown that it is made up of several distinct and important limestone formations, each of which is characterized by its own fauna. The lower members of the "Clift" limestone series,—the Clinton, Niagara and Helderberg,—have been described in the preceding chapter, and we now come to the consideration of the upper portion of the group; one which has been clearly proven not only to represent a distinct formation, but to belong to a different geological age from that of its associated strata, i. e. the Devonian.

The first identification of the Corniferous limestone in Ohio was made by Prof. Hall in 1841; and since that time its exposures on the islands in Lake Erie, at Sandusky, Delaware and Columbus, have been frequently visited by geologists coming from other states, and carefully studied by those who reside within our limits. Here, as in New York, the Corniferous has proved to be peculiarly rich in fossils—many of which are of special interest—and its fauna has hence come to be as well and widely known as that of any other formation in our state. Among the first of those who contributed to our knowledge of this fauna, was Mr. Joseph Sullivant of Columbus. He for many years owned quarries in this rock, opened in the vicinity of his place of residence, and took much pains to preserve all the more interesting fossils met with in working them. It is to him that we owe our first intimation of the existence, in this formation, of the interesting group of fossil fishes which have since made it so famous. I have endeavored to commemorate Mr. Sullivant's con-

tributions to our knowledge of the fauna of the Corniferous limestone, by associating his name with that of a large and remarkable fish (*Macropetalichthys Sullivanti*) of which he discovered the first specimens. In later years large collections of the fossils of the Corniferous limestone were made at Delaware by Mr. H. Hertzer; and on the islands of Lake Erie and about Sandusky by Dr. A. H. Agard, Mr. L. P. Wheelock and myself. These collections now include a great number of species of corals, mollusks, crustaceans and fishes; some of which are scarcely exceeded in interest by those derived from any other formation or locality in the world. Many of the most striking of these fossils will be found figured and described in the paleontological portion of this report.

The outcrops of the Corniferous limestone in Ohio form two widely separated belts, one on each side of the Cincinnati axis. Of these, the eastern crosses the centre of the state from the Lake to the Ohio river; including in its northern extension Kelly's Island, the eastern extremity of the Peninsula, and the city of Sandusky. Thence it extends southward, in a belt from ten to twelve miles wide, as far as Columbus. Here its outcrop begins to narrow; and before the south line of Pickaway county is reached, the Corniferous limestone is lost to view. This disappearance is due to its thinning out on the shore of the old Silurian island. It extends further south and east, as we know, for it is discoverable in Kentucky; but in southern Ohio it forms no outcrop, as its edge is covered by more recent strata, which reach further up on the side of the Cincinnati axis.

West of the great anticlinal the Corniferous belt crosses the Michigan line at Sylvania in Lucas county, thence curves round toward the southwest through Henry, Paulding and Van Wert; crossing the Indiana line centrally at the western point of contact of the latter counties. The Corniferous limestone also forms part of the Devonian island in Logan county. The central portion of this island is occupied by the Huron shale but most of its area is composed of a broad margin of Corniferous.

In the northern and middle portions of the state, the Corniferous limestone shows two well-marked and several less conspicuous subdivisions. Of these the uppermost is a blue, thin-beddded limestone, from fifteen to twenty feet in thickness, and is the rock quarried at Sandusky and Delaware. This I have usually designated as the *Sandusky limestone.* Below this we find a very light colored limestone which often contains balls and masses of chert. It is strikingly different in its mineral character, and somewhat different in its fossils from the overlying bed; though a large number of species are common to both. This lower subdivision I have called the *Columbus limestone;* as it is the rock opened in the quarries

near that city, and is that which supplied the stone of which the State House is constructed. It is often divided into several subordinate layers, which differ somewhat among themselves in lithological character and fossils, but as a general rule it is mainly a cream-colored and rather soft, magnesian limestone, composed almost entirely of the remains of marine organisms. On Kelley's Island and Middle Island in Lake Erie—as at the Falls of the Ohio—some of its beds are so largely composed of corals that they may be considered as ancient coral reefs. This rock contains very little earthy, but considerable organic matter, emits a fetid odor when struck with the hammer, and often holds petroleum and asphalt in the cells of its corals. These hydrocarbons are doubtless indigenous to the rock, and are derived from the soft parts of the animals whose remains are so abundant in it.

In the extreme upper portion of the Sandusky member of the Corniferous group, several characteristic Hamilton fossils are found in considerable abundance, such as *Spirifer mucronatus*, *Cyrtia Hamiltonensis*, etc. There are also found, throughout this portion of the formation, a number of species which are common to the Corniferous and Hamilton, such as *Atrypa reticularis*, *Atrypa aspera*, *Strophodonta demissa*, and, much more rarely, *Athyris spiriferoides*. From the presence of these fossils, I was for a long time led to doubt whether the Sandusky limestone should not be considered as a representative of the Hamilton rather than of the Corniferous group; but on gathering all the fossils of this formation, the list was found to include a much larger number of Corniferous than of Hamilton species; and all the Hamilton forms which penetrate below the surface of the Sandusky limestone are common to the Corniferous and the Hamilton. It should also be remarked that all the most conspicuous fossils of the Sandusky limestone are found in the lower members of the Corniferous group; and that its fauna is therefore much more Corniferous than Hamilton.

The mingling of the fauna of the Hamilton and Corniferous is apparently somewhat greater here than in New York; but this is readily explained by the fact that here, as in other portions of the western states, there were no such striking alternations of condition during the successive depositions of strata as are indicated at the east. An open sea prevailed through several successive periods at the west, and during these an unbroken series of limestone strata was formed, while at the east alternating shore and off-shore conditions interposed sheets of mechanical sediment, and gave more distinctness to the fauna of each formation.

The most striking fossils of the Corniferous group are fishes, of which the list now includes a large number of genera and species. These

remains are most abundant in the central portion of the Sandusky limestone, where a stratum is known among the quarry men as the *Fish bed;* the surface of one or two of the layers being, in some localities, almost completely covered with fragments—crania, jaws, teeth, &c.—of fishes. Many of the fossil fishes of the Corniferous will be found figured and described in another portion of this report. The most remarkable yet discovered are *Macropetalichthys* and *Onychodus*. Of these, the first seems to have left nothing but the cranium, which was a solid bony box composed of a number of large polygonal plates, that still remain firmly soldered together and give to the head somewhat tne aspect of that of the sturgeon. This fish seems to have been, like the sturgeon, too, without teeth; as a number of heads that have been found distinctly show the under surface, but bear no traces of a dental system. Neither scales nor spines have been discovered which could be associated with *Macropetalichthys*, and we may, therefore, infer that the body was covered simply with a tough skin, like most of the *Siluroids* (catfishes) of the present day; the brain alone having been protected by a bony envelope. In the largest individuals of *Macropetalichthys* the cranium had a length of from fifteen to eighteen inches; more commonly, however, the specimens obtained are from eight to twelve inches in length. The external surface of the cranium was covered with beautifully stellate, enameled tubercles, like those of Hugh Miller's *Asterolepis*.

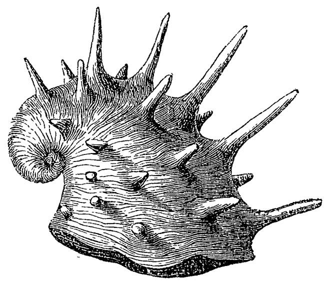
Onychodus was apparently a larger fish than *Macropetalichthys;* and was much better armed for attack and defense. The head in this genus was covered by a large number of bony tuberculated plates; which doubtless formed the exterior of a cartilaginous brain-box; but they were so imperfectly united that they are almost universally found detached and scattered about in the rock. *Onychodus* was provided with formidable jaws, which were sometimes a foot and a half in length, and were set with teeth three quarters of an inch long. The mandibles,—under jaws,—also embraced between their anterior extremities an arch of bone from which sprang a crest of seven hooked or sigmoidally curved conical teeth. These were many times larger than those of the jaws, and formed a single vertical row, which was apparently employed for piercing, much in the manner of the prow of a ram.

Some of the most common and characteristic of the molluscous fossils of the Corniferous group, and such as are not described in other portions of this report, are represented in the woodcuts below; and it is hoped, that by the help of these, and such other illustrations of its fossils as are now published, the formation will be readily recognized wherever it is found.

Fossils of the Corniferous limestone.

Figs. 28–31.

28.



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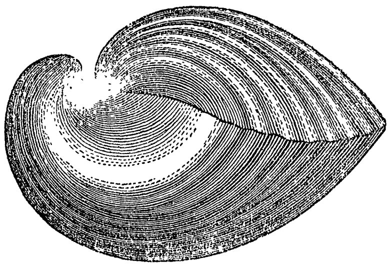

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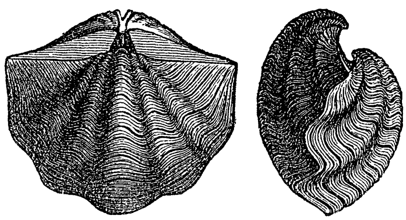

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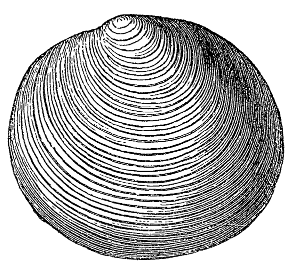


Fig. 28. *Platyceras dumosum*, Conrad.
" 29. *Pentamerus aratus*, Conrad.
" 30. *Spirifer raricosta*, Conrad.
" 31. *Lucina? proavia*, Goldfus.

Strange as it may seem,—since we know that the Corniferous limestone is an open sea deposit,—perhaps the most interesting of all its fossils are land plants. These consist of floated fragments of trunks and branches which belonged to the earliest land vegetation of which we find any traces in the valley of the Mississippi. The specimens obtained are as yet not very numerous, but the quarries at Sandusky and Delaware have each furnished two well defined species, beside fragments of others which are imperfectly preserved, and of which the botanical relationships have not yet been determined. Among these plants of the Corniferous limestone are three or four Tree Ferns, of which two are represented by well marked and beautiful specimens, very like some that are now growing upon the earth's surface. These I have named *Caulopteris antiqua* and *Caulopteris peregrina*. For reasons which have been given in the description of the Cincinnati arch, I think we must conclude that these plants grew upon the neighboring land of the old Silurian islands; and that

falling from the shore, or washed down by some ancient river, they were floated out to sea, and becoming waterlogged, sank in the calcareous sediment which was accumulating at the sea bottom.

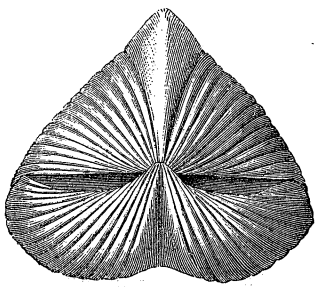
Among the other land plants found in the Corniferous limestone, I may mention a single specimen of *Lepidodendron*, found at Sandusky, which is apparently identical with a species (*L. Gaspianum*) obtained rom the Hamilton of New York and the Gaspe formation of Canada.

The impressions of sea weeds are as common in the Upper Corniferous in some places in Ohio, as they are in the Lower Corniferous—or Cauda Galli—of New York. The most abundant of these are species of *Spirophyton;* among which may be recognized all the forms figured by Vanuxem & Hall. The Columbus limestone being an open-sea sediment, contains few traces of sea weeds, but the Sandusky limestone, a shallow sea, or off-shore deposit, was their natural repository.

Fossils of the Corniferous limestone.

Figs. 32–36.

32.



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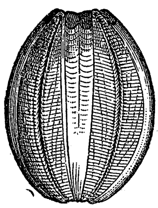

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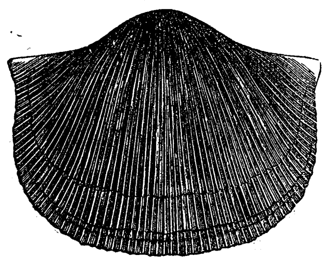

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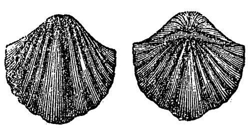

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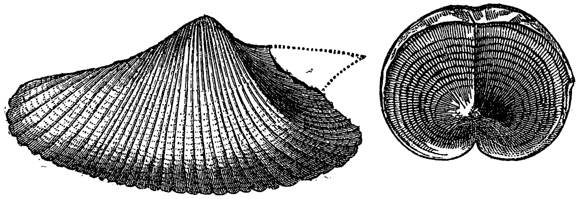


Fig. 32. *Spirifer acuminatus*, Conrad.
" 33. *Nucleocrinus Verneuili*, Troost.
" 34. *Strophodonta hemispherica*, Hall.
" 35. *Spirifer gregarius*, Hall.
" 36. *Conocardium trigonale*, Conrad.

The Corniferous limestone is no less important to our people economically than interesting scientifically; as it furnishes some of the best lime and building stone used in the state. The chemical composition of the different layers of the Corniferous is found to exhibit considerable differences; the Sandusky limestone containing much more earthy matter than the underlying Columbus limestone. The latter is highly crystalline, composed in many instances of the remains of corals and shells, and is therefore a very pure organic deposit. Nearly all the lime used on the Lake Shore east of Sandusky, and sent thence to the interior, is made from the lower members of the Corniferous limestone group. This is mostly derived from the quarries on Kelly's Island and at Marble Head, the extremity of the Peninsula. In some localities the Corniferous furnishes a building stone not inferior in beauty to any other found in the state. It supplies the stone generally used in Columbus, and, as has been stated, from this material the State House was built. On the Lake shore, where it competes with the sandstone from Berea and Amherst, the Corniferous limestone is less extensively used, but stone of fine quality, very homogeneous in texture and color, and capable of supplying blocks of any desired dimensions, is quarried by Messrs. Clemons at Marble Head. A still more beautiful variety of the Corniferous limestone,—a pure cream-colored homogenous rock—is quarried by Mr. Clark at Delphos, and, from this locality, is quite extensively distributed along the line of the Miami canal.

The upper member of the Corniferous limestone supplies the hard blue stone so much used for architectural purposes at Sandusky and Delaware.

I give below analyses of the lower member of the Corniferous limestone taken from the quarries of Marble Head and Kelley's Island:

Analyses of Corniferous limestone, by Prof. J. L. Cassells.

	1.	2.
Hygrometric moisture	0.80	0.80
Silica	0.40	0.15
Organic matter	0.05	0.02
Carbonate of Lime	78.00	83.20
Carbonate of Magnesia	20.75	15.83
Total	100,00	100.00

1. Limestone from quarry of G. W. Calkins, Kelley's Island.
2. " " " Messrs. Clemons, Marble Head.

The following list includes most of the fossils of the Corniferous limestone of Ohio which had been described previous to the organization of the present Geological Survey.

Atrypa reticularis.	*Lucina ? proavia.*
A. aspera.	*Gyroceras undulatum.*
Merista scitula.	*Euompholus DeCewi.*
M. nasuta.	*Loxonema Leda.*
Strophodonta demissa.	*Pleurotomaria Kearnyi.*
S. hemispherica.	*Turbo Shumardi.*
S. Pattersoni.	*Orthis propinqua.*
Spirifer gregarius.	*Dalmania selenurus.*
S. acuminatus.	*Proetus crassimarginatus.*
S. macra.	*Nucleocrinus Verneuili.*
S. macrothyris.	*Zaphrentis gigantea.*
S. raricosta.	*Cyathophyllum rugosum.*
S. Manni.	*Favosites Goldfusi.*
S. Grieri.	*F. polymorpha.*
Tentaculites scalaris.	*F. turbinata.*
Platyceras dumosum.	*Phillipsastrea gigantea.*

Further details of the structure and fossils of the Corniferous group will be found in the reports on the geology of Erie, Delaware and Franklin counties.

HAMILTON GROUP.

While the identification of the Corniferous limestone of Ohio with its equivalent in the New York series was early and accurately made, the group of rocks which overlie it have not been so readily correlated with strata holding, in a general way, the same position in other states. In regard to their relations not only much difference of opinion has existed, but grave errors have been committed; and we may reckon among the most important results of the first season's work of the present Geological Corps, the clearing up of the doubts and the rectification of the mistakes to which this group has given rise. In New York the Corniferous limestone is followed in the ascending series by the rocks of the Hamilton period, including, first, the Marcellus shale, then the Hamilton proper,—consisting of the Hamilton and Moscow shales, with the Tully and Encrinal limestones,—upon which rests the Genesee shale. The whole group is more than a thousand feet in thickness in central New York, but is diminished to half that, with the entire elimination of the limestone members, on the shores of Lake Erie. In central Ohio the succession of beds overlying the Corniferous, and thus corresponding in a general way to those I have enumerated, is as follows: First and lowest is the "Huron shale," a bituminous mass of three hundred feet

thick; above this the Waverly group, consisting of fine grained sandstones and shales five hundred feet in thickness; upon the Waverly the Carboniferous conglomerate. In Kentucky, Tennessee and Indiana, the Corniferous limestone, where present, is overlaid immediately by the Black shale, and, although some of the fossils which are generally supposed to be characteristic of the Hamilton are sometimes found in the Upper Corniferous, they are such as are common to the Corniferous and Hamilton, and no well defined Hamilton beds have been discovered there. When, however, we came to examine carefully this portion of the geological column in northern Ohio, we found certain strata present which are wanting in the localities cited, and such as enable us to make a more accurate determination of the relations of the different formations than had been done before. For example, at Prout's Station, eight miles south of Sandusky, the upper division of the Corniferous limestone is succeeded above by a bed of marl and marly limestone, ten to twenty feet in thickness, which contains great numbers of Hamilton fossils, with none which are peculiar to the Corniferous. The fossils to which I refer are *Spirifer mucronatus*, *Strophodonta demissa*, *Athyris spiriferoides*, *Cyrtia Hamiltonensis*, *Phacops bufo*, *Heliophyllum Halli*, *etc.* The marly limestone of this locality is immediately overlaid by the Huron shale. On the farm of D. C. Richmond, Esq., four miles south of Sandusky, the extreme upper layers of the Corniferous limestone are covered with impressions of *Spirifer mucronatus*, but mingled with *Spirifer gregarius*, *S. acuminatus* and various other well known Corniferous fossils. At Bellevue, a few miles south and west of the last mentioned locality, the Huron shale rests directly on the hard blue layers of the Sandusky limestone which contain *Strophodonta hemispherica* and scales and teeth of *Onychodus sigmoides*; which proves that here no true Hamilton is interposed between the Corniferous and Huron. In Tully township, Marion county, immediately beneath the Black shale, some thin layers of hard blue limestone are found which contain the well known Hamilton fossils, *Pterinea flabella*, *Nyassa arguta*, and *Tropidoleptus carinatus*. Below these come the layers of blue limestone which contain *Gyroceras undulatum*, *G. Ohioense*, etc., which characterize the Sandusky limestone. At Delaware a light gray marl is interposed between the Black shale and the Corniferous, containing small concretions which are formed around the bones and teeth of some small, and as yet undescribed fishes. This marl probably represents the Hamilton, but south of this point no trace of it has yet been detected. Mr. Winchell states that he has found *Cyrtia Hamiltonensis* and *Spirifer mucronatus* in the Sandusky limestone, at various points between Delaware and the Lake, and hence he has been disposed to

regard all the blue flaggy layers, which I have considered Upper Corniferous, as forming a part of the Hamilton group. In all the exposures, however, which I have examined of this member of the series, I have found Corniferous fossils greatly predominating and the truly Hamilton species confined to the uppermost layers. Combining the facts that have been stated and others of similar import, I am led to believe that we have, in the interval between Sandusky and Columbus, the extreme western edge of the Hamilton formation. In certain localities there are well defined beds which represent this group, while in others the true Hamilton is wanting, and the Huron shale rests directly upon the Corniferous limestone. It seems true, also, that we have in Ohio a mingling of the Hamilton and Corniferous faunae to a greater extent than is observable in New York. As has been before stated, the Hamilton group was deposited in the same basin with the Corniferous limestone, but when that basin had become shallower and narrower than before. In that part of Ohio which has been referred to in the preceding remarks, the Cincinnati arch formed the shore of the Hamilton sea, and as the submergence of the arch was much less during the Hamilton than in the Corniferous period, the sediments of the Hamilton reach a less distance up its flank than those of the Corniferous.

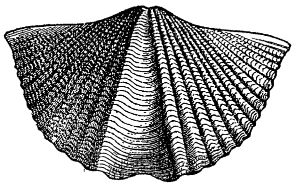
On the west side of the anticlinal the Corniferous limestone graduates above into laminated marly layers which contain many of the fossils of the Hamilton group. These are found over a long line of outcrop, running from Antwerp down the Maumee to Defiance and thence, by a somewhat tortuous course to the Michigan line near Sylvania. In this part of the state the Hamilton is apparently thicker and more persistent than on the east side of the anticlinal, but it shades into the Corniferous so gradually that it is difficult to draw the line between them. North of Ohio, in Michigan and western Canada, the Hamilton group is much thicker and better defined than anywhere within our state.

From all the facts before us we learn that the line of outcrop of the Hamilton sweeps around the Cincinnati arch, parallel with that of the Corniferous, but everywhere more distant from its axis, not as the result of erosion, but because the land area was broader and that of the sea narrower during the Hamilton period than before.

Fossils of the Hamilton Group.

Figs. 37–42.

37.



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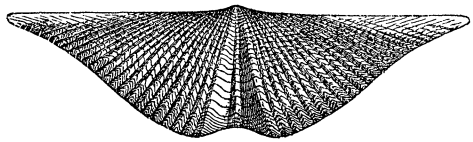

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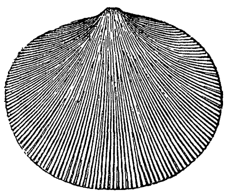

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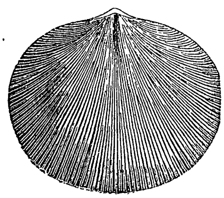

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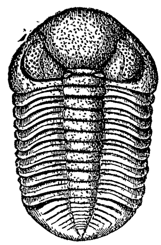

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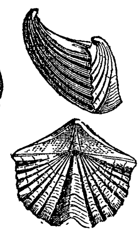


Fig. 37. *Spirifer mucronatus*, Conrad, narrow variety.
" 38. *S. mucronatus*, broad form.
" 39–40. *Orthis Vanuxemi*, Billings.
" 41. *Phacops bufo*, Green.
" 42. *Cyrtia Hamiltonensis*, Hall.

HURON SHALE.

One of the most strongly marked elements in the geological structure of our state is a mass of black, bituminous shale, from 200 to 350 feet in thickness, which was designated by the first Geological Corps as the *Black Shale.* This formation underlies all the northwestern corner of Ohio, including the counties of Williams, Fulton and Defiance. It also forms a belt of outcrop, ten to twenty miles in width, extending from the mouth of the Huron to that of the Scioto. It was formerly supposed that the Lake shore was composed of the Huron shale from near Sandusky to the Pennsylvania line, but our later observations have proved that in Lorain county this formation dips eastward below the Lake level; and from this point to the eastern line of the state the margin of the Lake is formed by the overlying beds of blue and green shale which I have called the *Erie Shale.*

The general aspects of the Huron shale are very well exhibited in the fine sections afforded by the banks of the Scioto and the Ohio near Ports-

mouth, at its exposures on the Big Walnut, east of Columbus, at Worthington, Delaware, on the banks of the Huron, etc. In the central and southern parts of the state, the Huron shale forms a nearly homogeneous mass, but at its northerly outcrops it is somewhat interstratified with the overlying Erie shale. For the most part it consists of thinly laminated bituminous shale, very black when first quarried, but, by the oxidation of its carbon, weathering to gray. It is also, when protected from the action of the air, very compact, and may be taken out in large and solid blocks. These soon split up, however, on exposure, and cliffs formed by the outcrops of the shale usually present a slope, covered with small flakes of the decomposing material, often stained red by the oxidation of iron, which it contains normally as sulphide. The amount of combustible matter included in it varies from ten to twenty-five per cent., and it has been successfully employed for the manufacture of oil by distillation. It also contains, in various localities, sheets of asphalt or asphaltic coal, closely resembling Albertite in appearance and properties. These sheets are sometimes interlaminated with the shale, and sometimes fill vertical fissures. One of the latter, found near Avon Point, Lorain county, is two and a half inches thick.

Oil and gas springs are also constantly associated with the outcrops of this formation. I shall have occasion to refer to them again, but I will say here in passing that we have every reason to believe that the black shales of which the Huron forms the western extension, supply all the oil to the wells on Oil Creek, and the gas to the gas wells on the Lake shore. The hydro-carbons which escape from the outcrops of the Huron in Ohio, are apparently the product of a constant spontaneous distillation; and if we had here an overlying series of fissured and porous strata to receive them, and still higher an impervious stratum serving as a cover to retain them—so that we could draw from the accumulated secretion of ages—we might have, in many localities, wells of gas and oil which would richly remunerate their owners. Under the present circumstances, however, both gas and oil generally flow away as fast as formed; so that most of our efforts to obtain them in paying quantities have been unsuccessful. The asphalt to which I have referred, is, in my judgment, nothing else than the solid residue, left in the spontaneous distillation of petroleum.

Almost everywhere the exposures of the Huron shale show traces of marine vegetation, but beyond these it is proverbially barren of fossils. In the southern part of Ohio, as in Kentucky and Tennessee, small species of *Lingula* and *Discina* are locally somewhat abundant in this formation, but, until quite recently, it was supposed to be destitute of fossils of magnitude and interest. Such being its character, it is not surprising

that much diversity of opinion has prevailed in regard to the age and relations of the deposit. The *Lingula* and *Discina* to which I have referred were at one time supposed to be identical with *L. spatulata* and *D. lodensis*, and hence, as affording evidence of its equivalence to the Genesee shale. It was shown, however, some years since, that the identification of these fossils was erroneous; and that they were new species and therefore of no value for determining the relations of the formation. Most geologists who have since had occasion to refer to the Huron shale, have called it *Marcellus*, without, however, giving any good reason for so doing. The determination of the age of this deposit was, therefore, one of the first duties which presented itself to us after the organization of the present Geological Survey. Previous to this time, however, Rev. H. Hertzer, by his discoveries, at Delaware, of the remains of huge fishes in the calcareous concretions of the Huron shale, had proved that, instead of being without fossils, this formation contained the most remarkable and interesting ones yet brought to light in the state. These were, however, also, of species new to science, and helped us in no respect in our efforts to determine the age of the rock, except to show that it formed part of the Devonian system. For a long time our search for known fossils in the Huron shale was unavailing, but we ultimately found a few which belong to the Portage group of New York, and these, with a careful tracing of the rocks along the Lake shore, enable us to say with confidence that the Huron shale represents mainly the Gardeau shale of the New York geologists, and with this whatever we have of the underlying Genesee. The fossils to which I refer are *Clymenia? complanata*, *Chonetes? speciosa*, *Orthoceras aciculum* and *Leiorhynchus quadricosta*. A small *Discina*, a *Loxonema* and two species of obscure conchifers were also found in the formation, but had no bearing on the question before us. Of the fossils enumerated *Clymenia complanata* may be said to be absolutely diagnostic of the Portage group.

On tracing the rocks of New York westward, it was also found that the black bituminous shales are far more persistent than their associated green argillaceous shales and sandstones. Where last observed the Cashaqua shale—which separates the *black* shales of the Genesee and Portage—had diminished to a thickness of thirty feet; and it undoubtedly runs out before reaching Ohio.

That the Huron shale is not the equivalent of the Marcellus is proved not only by the presence in it of Portage fossils, but by the well marked Hamilton shales which we have shown to underlie it. If the Huron were Marcellus, it would be beneath the Hamilton. The reasons which operated in the application of the name Huron to the "Black slate" are given in the chapter on the geological relations of our rocks.

The lower portion of the Huron shale contains, in all localities where it is visible, concretions of impure carbonate of lime. These are sometimes irregular in form, but perhaps oftener are nearly spherical, and attain a large size. Some which may be seen at Worthington, in Franklin county, are ten feet in diameter and nearly globular. They have evidently been formed in the position they occupy; as many of them show a peculiar funnel shaped depression which marks the upper surface. The layers of the shale are seen to be curved over and around these septaria; a fact which has been considered as proof that the laminae of the shale were deposited over them after they had obtained their present size and form. This appearance is, however, due entirely to the loss of volume in the shale, consequent upon vertical compression from overlying rocks. All such argillaceous strata shrink one-half or more when compressed from mud to rock. The solid concretions have yielded little or nothing to this compression, and hence the layers of shale are curved around them.

The source of the carbonaceous matter which is so striking a feature in the Huron shale, has presented a difficult problem to all those who have thought upon the subject. The mode of accumulation of the mechanical sediments we can readily comprehend, and also the manner in which the organic materials that compose our limestones were deposited in the bottom of the ocean. We can satisfy ourselves too as to the mode in which the beds of coal in the Carboniferous series have been formed; but the production and peculiar distribution of the carbonaceous matter with which this formation is charged, are phenomena not so easy of explanation.

The development of black shales at the horizon of our Huron in Canada, New York and Pennsylvania, has already been noticed.

As we go south from Ohio, the Huron shale is found underlying all the Carboniferous rocks of Kentucky, and is a marked feature in the geological sections of Tennessee. There, however, it is diminished in volume, having a thickness not generally greater than from 30 to 60 feet, but is more compact and homogeneous, and contains a larger percentage of bituminons matter than further north. In Indiana and Michigan the "Black shale" is also met with, and it is evident that it once occupied an area equal to that of several of our largest states.

It appears from the relations of the Huron shale to the rocks above and below, as well as from its own internal structure, that the materials which compose it have been accumulated in a quiet water-basin. It rests upon the limestones that formed the bottom of the Corniferous sea, and is succeeded above by fine, argillaceous shales, very evenly and reg-

ularly stratified; all indicating a quiet process of deposition, and comparative remoteness from land surfaces and shore lines.

Without discussing this problem in all its bearings, I may say that the results of such study as I have given to it, may be briefly stated as follows:

First: The nature of the sediments which form the Huron shale; the exceeding fineness of the mineral matter, the large percentage and uniform dissemination of carbon, the peculiar composition of this carbonaceous element—consisting mainly of hydro-carbons,—the abundance of marine plants and the absence of terrestrial vegetation; all combine to show that it was deposited in an open sea and not immediately adjacent to the land.

Second: Under such circumstances we are compelled to attribute the carbonaceous matter to marine vegetation or to marine animals. If it were derived from marine animals, such as we know have contributed largely to the organic constituents of some rocks—the bituminous limestones for example—we should find much more abundant traces of their structures than we now do; since they are, in fact, almost entirely absent. We are, therefore, compelled to consider this accumulation of bituminous matter as the result of the growth of sea weeds in marine basins.

Third: Most marine plants with which we are acquainted grow upon the shore, or in shallow water, and we can hardly imagine so large an area as that occupied by the Huron shale covered with a growth of shallow water plants without its bearing evidence in some locality of shore lines. It is true, however, that a great growth of aquatic vegetation sometimes takes place remote from the land, and where the plants have no attachment to the sea bottom. Of these areas we have a type in the "Sargasso Sea" through which Columbus ploughed his way when making the voyage that resulted in the discovery of America. Here, as in the other similar sheets of sea weed, the vegetation floats upon the surface of the water and maintains a vigorous and luxuriant growth without connection with shore or bottom. Corresponding to this growth must be the decomposition of vegetable tissue on a large scale. The products of such decomposition would fall to the ocean bottom as finely comminuted carbonaceous mud, mingled with stems and fronds detached by violence or decay. Under all such sheets of vegetation, in a sea where a fine mechanical sediment is being deposited, we must necessarily have an accumulation of mud containing a large percentage of carbonaceous matter; in other words, the elements of a bituminous shale. Waiting the demonstrative solution of the problem, which patient and exhaustive study will doubtless sometime furnish, I offer, as a possible explanation of the peculiar features of the Huron shale, the suggestion that its carbon was

derived from vegetation which lined the shores and covered the surface of a quiet and almost land-surrounded sea.

The remarkable fossil fishes of the Huron shale, to which reference has been made, will be found described in detail in the paleontological portion of this report. A few words in regard to their geographical distribution, and the circumstances of their discovery may, however, not be without interest here.

The two most extraordinary of these fishes, *Dinichthys Hertzeri* and *Aspidichthys clavatus* were both first found by Rev. H. Hertzer at Delaware, Delaware County, while he was stationed there as an itinerant minister of the German Methodist Church. In examining the concretions contained in the Huron shale, he detected in some of them fragments of large bones. These he worked out, with incredible patience, from their hard and tough matrix, and submitted them to me for examination. I found them to be the remains of fishes of larger size and more massive structure than any fossil fishes before known; and that they constituted new genera and species, but exhibited affinities with the Placoderms *Coccosteus, Ptericthys* and *Asterolepis* of the Old Red sandstone of Scotland. A large number of jaws and cranial plates of *Dinichthys* have since been found, so that I am able to reconstruct the head in a manner quite satisfactory. This was about three feet long by two broad, covered with strong, bony plates and furnished with massive jaws and teeth. Of *Aspidichthys* only the central plate of the back has yet been found, and that not in the concretions, but lying in the laminated shale. Although imperfect, this plate is 13 by 17 inches long, and more than an inch in thickness at its centre. It apparently corresponds to the central plate of the carapace of *Pterichthys*, but is nearly one hundred times as large.

I have recently found numerous specimens of jaws and plates of *Dinichthys;* though none so fine as those obtained at Delaware; in the concretions which had fallen out of the Huron shale at Monroeville on the Huron river.

About the time of Mr. Hertzer's discovery of fish remains at Delaware, Mr. J. Terrell, of Elyria, found several large, water-worn fragments of black, mineralized bone on the beach of the Lake west of Avon Point. These had evidently fallen out of the cliff of Huron shale which here forms the Lake shore. On examining these bones, when brought to Cleveland by Mr. Terrell, I discovered that they were portions of the "*os medium dorsi*" of *Dinichthys.* This is a plate which covered the arch of the back immediately behind the head; and was, in some cases, two feet in length and breadth, and more than two inches thick at its central anterior portion. Since his discovery of the first of these interesting relics, Mr. Terrell has

pursued the search for them with much enthusiasm and success. Among some hundreds of less important bones, two nearly complete crania and two complete dorsal shields have been found in this locality by Mr. Terrell, Prof. G. N. Allen and Mr. A. W. Wheat.

The economic value of the Huron shale will be more fully discussed in that volume of our report devoted to Economic Geology, but a brief allusion to the subject will not be out of place here.

I have already referred to the Huron shale as a probable source of the greater part of the petroleum obtained in this country. This view, which was first advanced in an article on the "Rock Oils of Ohio," published in the Ohio Agricultural Report for 1869, has been opposed by high authority, but is, I think, now quite generally accepted by geologists. The arguments on this question, will be given more at length in another place, but I may say, in passing, that the considerations which have led me to adopt this view, are briefly these:

First: We have in the Huron shale a vast repository of solid hydro-carbonaceous matter, which may be made to yield from ten to twenty gallons of oil to the ton by artificial distillation. Like all other organic matter this is constantly undergoing *spontaneous* distillation, except where hermetically sealed deep under rock and water. This results in the formation of oil and gas, closely resembling those which we make artificially from the same substance; the manufactured differing from the natural products only because we can not imitate accurately the processes of nature.

Second: A line of oil and gas springs marks the outcrop of the Huron shale from central New York to Tennessee. The rock itself is frequently found saturated with petroleum, and the overlying strata, if porous, are sure to be more or less impregnated with it. Collateral facts, having the same import, may be cited. For example: a line of gas and oil springs similar to that already referred to, follows the outcrop of the Cleveland shale; a carbonaceous stratum in the overlying Waverly group, but the quantity of liquid and gaseous hydro-carbons generated here is much less than that evolved from the Huron shale, because one is 50, the other 300 feet in thickness. Again: the emanations of oil and gas from the Lower Silurian rocks at Collingwood, Canada, and on the upper Cumberland river, Kentucky, are associated with similar deposits of black shale which represent the Utica slate of New York.

Third: The wells on Oil Creek penetrate the strata immediately overlying the Huron shale, and the oil is obtained from the fissured and porous sheets of sandstone of the Portage and Chemung groups, which lie just above the Huron and offer convenient reservoirs for the oil it

furnishes. It is a well known fact that wells, sunk into the Black shale, yield no considerable quantity of oil, unless from the strata which rest upon it. The oil wells of Mecca, Trumbull county, and Liverpool, Medina county, hold precisely the same relation to the Cleveland shale as do those of Oil Creek to the Huron. The same may be said with regard to the relations of the Collingwood and Burksville wells to the Utica slate.

The opposing theory of Prof. T. S. Hunt, which makes petroleum the product of primary and not secondary decomposition of organic tissue, and which derives the petroleum of the different oil regions from underlying limestones,—especially the Corniferous,—fails entirely to harmonize with my view of the genesis of petroleum, or with any of the facts which I have observed in regard to the circumstances of its production. Very briefly, my objections to Prof. Hunt's theory are these :

1. The Corniferous limestone contains but a small percentage of hydro-carbons in all of the thousands of localities where I have examined it. Very little oil or gas can be produced from it artificially, and oil and gas springs are exceedingly rare in the areas where it underlies the surface. It is true that, like all limestones, this contains a large amount of *carbon*, but, as Prof. Wurtz has suggested, the carbon in limestones is locked up beyond the reach of spontaneous distillation, and, for its liberation, a higher heat is required than that which produces the metamorphism of limestone into marble. Thus, the formation of limestone is exhaustive of an element essential to animal and plant life, and if it should continue as it has gone on in past geological ages, it will result in universal death.

2. No considerable quantity of petroleum is derived through wells from the Corniferous, the Niagara, or any other limestone. Even at Chicago, where the Niagara is saturated with petroleum—here undoubtedly indigenous and derived from animal matter—all efforts to obtain it in quantity by boring have been failures. In those portions of Ohio where the Corniferous limestone forms the surface rock, borings for oil have been universally unsuccessful; and in those portions of Kentucky, cited by Dr. Hunt as proving the derivation of petroleum from the Corniferous limestone, no Corniferous exists. In the oil region of western Canada, where the theory of Prof. Hunt was formed, there is no evidence whatever that the oil is derived from the Corniferous limestone. In fact, the proof is positive that at least a part of it comes from a lower horizon; for some of the deeper wells have drawn oil from points far below the Corniferous. This district is in the line of the Cincinnati arch, which here, as on the islands in Lake Erie, shows evidence of dis-

turbance long subsequent to its original upheaval. It therefore seems to me probable that most of the oil of this region is derived from the underlying Silurian Collingwood shale.

As is known, the wells which in Ohio have been sunk to the vicinity of the Huron shale, have very generally yielded oil, but only in small quantity. The difference in the productiveness of this oil horizon in Ohio and Pennsylvania, has caused considerable surprise and disappointment. It seems to me, however, easy of explanation. On Oil Creek the strata which underlie the surface are: First, the argillaceous shales of the Waverly group and Upper Chemung, which form the sides and bottom, of the valley; below these, several beds of sandstone, interstratified with shale which belong to the Upper Chemung and Lower Portage groups; still lower, the black shales of the Portage and Genesee, having a thickness of several hundred feet. These strata have all felt the disturbing influence of the forces which raised the Alleghany mountains. Here, then, we have a peculiar geological substructure, such as is specially favorable to the production and accumulation of petroleum, and such as must be more or less perfectly paralleled elsewhere to make productive, or at least flowing wells possible. This structure consists in a great mass of carbonaceous strata below, more or less disturbed and loosened, from which the oil is supplied in a constant and relatively copious flow; above this, strata of porous, jointed sandstone, serving as reservoirs where the constant product of oil and gas may accumulate for ages; still higher, argillaceous strata, impervious in their texture, and not capable of being opened by fissures, forming a tight cover which prevents their escape. As we go west from Oil Creek into Ohio, we find both the structure and the composition of the rocks overlying the Huron exhibiting a progressive change. In the first place, the "sandrocks" of the Oil Creek series thin out and give place to fine and impervious, argillaceous shales. Thus, the reservoirs for the oil diminish in capacity and ultimately disappear. In the second place, the strata all become more homogeneous and compact, and the fissures which are so numerous and so necessary on Oil Creek, are wanting. In Pennsylvania there are many "dry wells" which are failures because bored in solid blocks of rock in which no fissures are struck. In Ohio, such wells have proved to be the almost universal rule, and none of the wells yet bored have opened reservoirs from which oil has been obtained in paying quantities.

Although no successful oil wells have been bored in the strata I have enumerated within the limits of our state, the quantity of carburetted hydrogen gas which escapes from some of these wells, has been so great as to be worthy of notice in a review of the economic products of the

Huron shale. As carburetted hydrogen produces a brilliant light in combustion, it is largely manufactured and used for the illumination of cities and residences. So extensively is it employed for this purpose, that it may be regarded as an indispensable element in our modern civilization. Since its value has been so fully demonstrated, it is not strange that efforts have been made to utilize the immense quantity of gas which flows from wells and springs in so many localities. The Chinese have, for hundreds of years, used for lighting and heating, the gas which emanates from the earth in several provinces of their country. In the United States, the gas which issues from the salt wells of the Kanawha valley, has been long employed as a fuel for the evaporation of the brine. The town of Fredonia, in western New York, has been, for more than forty years, fully or partially lighted by gas derived from springs at that place. In the borings made for oil at various localities in the western states, the gas produced so abundantly has been generally regarded as a useless, frequently an inconvenient and dangerous product. Within a year or two past, however, this gas has been utilized in numerous instances, and already a large number of wells have been bored for the express purpose of obtaining it. In some cases these wells have been highly productive, furnishing an abundance of material for heating and lighting in its most convenient and manageable form; so that this "natural gas" deserves to be reckoned as one of the important elements in our mineral resources. At Erie, Pennsylvania, there are now more than thirty wells in successful operation, most of which have been bored for the special purpose of obtaining gas. Similar gas wells exist within the limits of our own state at Conneaut, Ashtabula, Painesville and Cleveland. All these are bored in the Erie shale, and draw their gas from above the surface of the Huron. One of the most successful of the wells bored for gas in Ohio is that of General J. S. Casement of Painesville. This is situated on the east side of the town, is 700 feet deep, and passes through the following materials:

		FEET.
1.	Drift clay and gravel	40
2.	Erie shale, "soap stone rock,"	648
3.	Huron shale, very black and bituminous, with a strong smell of oil...	12

The gas was found in a fissure struck in the Erie shale; the quantity has never been measured, but it is more than sufficient for heating and lighting every part of General Casement's establishment. The comfort and elegance imparted to it by an abundant flow of odorless, inflammable gas, can hardly be appreciated without being seen; every room in the

house is brilliantly lighted, and every fire, in the furnace below, in the kitchen range as well as in the grates of the parlors and chambers, is fed by a fuel which gives a cheerful flame, is supplied and turned off by turning a stop cock, makes no smoke and leaves no ashes. So great a luxury as this makes enviable the fortune of the man who possesses it, and is certainly worth some trouble and expense to those who would enjoy it.

The most remarkable of the wells which draw their gas from the Huron shale, are two bored by Peter Neff, Esq., near Millwood in Knox county. These wells were sunk in 1866; beginning in the Waverly, and reaching to the Huron shale. At a depth of about 600 feet, in each well, a fissure was struck from which gas issued in such volume as to throw out the boring tools and form a jet of water more than 100 feet in height. One of these wells has been tubed so as to exclude the water, and gas has continued for six years to escape from it in such quantity as to produce, as it rushes through a two and a half inch pipe, a sound that may be heard at a considerable distance. When ignited, the gas forms a jet of flame three feet in diameter and fifteen feet long. The other well, which has never been tubed, constantly ejects, at intervals of one minute, the water that fills it. It thus forms an intermittent fountain one hundred and twenty feet in height. The derrick set over this well has a height of sixty feet. In winter it becomes encased in ice, and forms a huge translucent chimney, through which, at regular intervals of one minute, a mingled current of gas and water rushes to twice its height. By cutting through this hollow cylinder at its base and igniting the gas in a paroxysm, it affords a magnificent spectacle; a fountain of mingled water and fire which brilliantly illuminates the icy chimney. No accurate measurement has been made of the gas escaping from these wells, but it is estimated to be sufficient to light a large city.

Whether the Huron shale has other economic value than that which has been referred to, remains to be proven, but it seems to me to be a formation of great, and as yet imperfectly developed capabilities. When we consider that it underlies fully one half the state with an average thickness of over three hundred feet, and that it contains probably fifteen per cent. of combustible matter—and is therefore equivalent to a coal seam fifty feet in thickness over all the area it occupies—it will be seen that it is by far the greatest store house of power which we possess. Unfortunately the carbonaceous matter it contains is so distributed through its mineral constituents as to have no value as a fuel. Experiments have proved that oil may be extracted from it cheaply by distillation, but at present it can be still more cheaply obtained, already distilled, from the

oil wells. Should our supply of petroleum fail, it is certain that the Huron shale can furnish us an inexhaustible supply of illuminating and lubricating oil for less than double the prices now paid. Hence we may consider this deposit as a guarantee that our people may always have a a cheap illuminator, and will never be compelled to return to the dark days of twenty years ago.

It is also to be expected that in the progress of discovery new methods will be devised for utilizing the enormous amount of power now locked up in the Huron shale, and that it will not always be permitted to lie as now a neglected element in the resources of our state.

ERIE SHALE.

I designate by this name a group of greenish or bluish argillaceous shales which form the Lake shore from the Pennsylvania line to Avon point. The base of this series on the eastern margin of the state is below the Lake level, so we have no means of ascertaining what its precise thickness is in that vicinity. Toward the west it rapidly thins out and is lost sight of south and west of the Vermillion river.

The prevailing lithological character of this deposit is very well shown in the sections of the cliff bordering the Lake in the vicinity of Cleveland; and it is here seen to consist of green, gray and blue shales, generally very soft and fine, interstratified with sheets of micaceous, silvery sandstone from half an inch to two inches in thickness, with flattened, lenticular masses of argillaceous iron ore. On the eastern border of the state this formation is much more sandy, and includes some sandstone layers which are thick enough to be used for purposes of construction; also some thin sheets of impure limestones, crowded with fossils.

West of Cleveland the Erie shales are seen to form two beds or groups of strata, of which the upper, nearly 100 feet in thickness, consists of shales such as I have described, with thin bands of sandstone which sometimes are sufficiently thick and firm to be used as flagging. The lower series consists almost exclusively of blue and green shales, with thin strata of iron ore; the whole weathering in smooth hemogeneous cliffs of which the prevailing color is a greenish gray. These two groups are well exposed in the cliffs which form the Lake shore between the Cuyahoga and Rocky River; the lower beds composing that cliff for about three miles west of the Cuyahoga. The upper series there comes in with a strong westerly dip by which it is carried down to the Lake surface just east of the mouth of Rocky River, and forms the cliffs bordering this stream at its mouth, and for two or three miles above. From this point westward the beds lie nearly horizontal until at Avon point they again

rise toward the west, and are succeeded by the lower group, which in turn gives place to the Huron shale. As a general rule the Erie shales are remarkably destitute of fossils, and from this cause their exact geological age was for a long time misunderstood, and has been accurately determined only recently and with much study. From their lithological resemblance to the shales of the Portage group in New York, and from their apparent continuity with these, the Erie shales have been generally considered as their equivalent, while the overlying Cuyahoga shale, and other beds which form the northern extension of the Waverly group, have been regarded as the western prolongation of the Chemung rocks of New York. It was our good fortune, however, during our first season of field work, to obtain from several localities in the Erie shales fossils which prove beyond question that the upper portion of these shales are the representatives of the Chemung; and while, from the want of further evidence of the age of the lower beds, we are as yet unable to assert positively that they are continuous with the upper portion of the Portage group, there is scarcely room for doubt that they are the western extension of the "Portage sandstones." In New York these rest on the Gardeau shale, which, as we have seen, forms the chief part of our Huron. If no longer sandstones in Ohio, it is because, following the general law, they have become thinner and finer in coming westward.

Collections of fossils, which include great numbers of individuals, but not many genera and species, were made by the members of our Corps in the bottoms of the gorges formed by Tinker's Creek and Chippeway Creek—tributaries of the Cuyahoga in Cuyahoga County—in the valleys of the Chagrin near Euclid, of Big Creek in Lake County, and of Conneaut Creek in Ashtabula County; as well as in the beds of the tributaries of Grand River in the northern part of Trumbull. These fossils include, with some new forms, the following species characteristic of the Chemung in New York: *Spirifer disjunctus*, *S. altus*, *Leiorhynchus mesacostalis*, *Orthis Tioga*, etc. The evidence furnished by this group of fossils definately fixes the geological position of at least the upper portion of the Erie shale, and dissipates the obscurity that has heretofore hung over the formation.

On the eastern border of the state, the Erie shale has a thickness of nearly 1000 feet; at Painesville, Lake County, about 800 feet; in the valley of the Cuyahoga, between 400 and 500 feet; while in the central and southern part of the state the formation is either entirely absent, or is reduced to insignificant dimensions, and exhibits no characters by which it can be distinguished from the overlying Waverly group.

In northern Ohio the Waverly contains, near its base, a stratum of black bituminous shale from 20 to 60 feet in thickness, which I have

called the Cleveland shale. Lower Carboniferous fossils occur in abundance beneath this shale, but reach only a few feet below it. Greenish argillaceous shales come in always within 50 feet, sometimes immediately below the Cleveland shale, and in these we find all the characteristic fossils of the Erie.

On the banks of the Vermillion river in Huron County, the Cleveland shale seems to come down directly on the Huron, and the Erie shale has apparently disappeared.

In southern Ohio, on the banks of the Scioto, a stratum of black shale 15 to 20 feet in thickness is found 137 feet above the Huron, and this is probably the equivalent of the Cleveland shale. The strata which separate this from the Huron have yielded no fossils as yet, but in lithological character they are undistinguishable from the Waverly above; and we have considered them as a part of that formation. If the Erie shale has any representative in this portion of the state, it is to be found, however, in the interval to which I have alluded.

In Kentucky and Tennessee no traces of the Chemung or Erie shales have been discovered; and there the Waverly with Carboniferous fossils rests directly upon the Huron shale. West of the Cincinnati anticlinal a few of the fossils of the Chemung have been found in calcareous strata even as far west as Nevada, but the Chemung of New York and the Erie of Ohio, as characterized by lithological features and fauna, may be said to be wanting in all localities west of the Cincinnati arch.

From all the facts which have come to my knowledge, bearing on the history of the Erie shale, I am led to the following conclusions: First: The formation was deposited in a water-basin much more shallow and narrower than that in which the Huron shale accumulated; and in Ohio off-shore conditions had, in the Erie epoch, succeeded the wide-spread Huron sea. Second: The alternations of fine shales and coarse sandstones and conglomerates, which compose the Upper Portage and Chemung in New York, are proofs of oscillations of sea level which sometimes brought shore lines to the margin of Ohio, but never produced any dry land in the eastern part of the state. Third: The spread of the enormously thick sheets of mechanical sediments which make up the Upper Portage and Chemung (Erie) over so large a part of New York, Pennsylvania, and Ohio, is a record of a gradual but profound subsidence of most of the area lying between the Cincinnati arch and the Blue Ridge. We also learn from this record that the subsidence was greatest toward the East; was slow and often interrupted, but finally resulted in filling the northern and eastern part of the trough with three thousand feet of shore and shallow-water deposits. We know them to be such by their lith-

ological character, and by the ripple marks and impressions of land plants which they contain. The northern limits of the sea in which these sediments accumulated are not traceable on account of their removal by erosion from the great basin now partly filled by Lake Erie and Lake Ontario. The Catskill mountains and the highlands of Portage and Chemung rocks which stretch from them to Ohio, measure at the same time the enormous thickness of the deposits and the stupendous erosion they have suffered toward the North. Fifth: The commencement of the epoch of the deposition of this series of mechanical sediments, introduced a new and great era in geological history; *and it was in fact the beginning of the Carboniferous period.* This subject will be more fully discussed in the chapter on the general structure and history of the Carboniferous System—which will form part of another volume of this report—but I may here say, in passing, that in my judgment the line of separation between the Devonian and Carboniferous systems would be more naturally drawn at the base of the Portage sandstone than where it is now placed, for there a new circle of deposits begins, the products of a new submergence of the continent which culminated in the deposition of the wide-spread marine, organic sediment of the Lower Carboniferous limestone.

The series of strata which begins with the mechanical sediments of the Portage has also a fauna which is much more Carboniferous than Devonian in character. The break at the top of the Hamilton—calling the Huron Hamilton—is not complete, we know; for there are connecting links between the fauna of the Hamilton and that of the Chemung; but there are also connecting links between the Lower and Upper Silurian (Cincinnati and Clinton,) and between the Upper Silurian and Devonian, (Helderberg and Oriskany). The abundance of species of *Productus* and *Productella* in the fauna of the Chemung will suggest itself at once as a marked Carboniferous feature.

I have already alluded, though briefly, to the fossils of the Erie shale. The list of species new and old which we have found in the formation is not a long one, but in some localities the individuals of some species are very numerous. Near Kelloggsville and at Ashtabula in Ashtabula county, some thin sheets of impure limestone contained in the Erie shale are not only filled but composed of the shells of a new species of *Leiorhynchus (L. Newberryi Hall)*. In Jefferson, Morgan and Pierrepoint in the same county, *Spirifer disjunctus, S. altus, Orthis Tioga, Productella speciosa, Leiorhynchus mesacostalis,* and species, probably new, of *Meristella* and *Euomphalus* are locally very abundant. On Big Creek in Lake County a species of *Leiorhynchus* which I cannot distinguish from *L. quadricosta,* was found by Mr. Sherwood; and on Paine's Creek in Leroy, small concretions occur in the shale, many of which contain as nuclei two new and

very interesting crustaceans. Of these one is probably a species of *Ceratiocaris;* the other is allied to this but apparently belongs to a genus hitherto undescribed.

The economic value of the Erie shale is not great; probably less indeed than that of any other formation found in the state. Oil and gas are obtained from it, as has been stated, but are not indigenous in it, and are derived from the Huron shale below. When extensively eroded, the Erie shale has sometimes left a sufficient number of nodules and plates of iron ore in stream beds to be worth collecting, and such accumulations formed an important source of supply of ore to the first charcoal furnaces located on the Lake shore. No iron is however now made from this ore.

The soil formed by the decomposition of the Erie shale is wet and tenacious, as might have been expected from its argillaceous character. Though not adapted to general tillage, it has proved well suited to the growth of grass, and a large part of the dairy farms of the Western Reserve owe the peculiar properties of their soil to the Erie shale, either decomposed in place, or ground up and spread over other rocks by Drift agents. The soil furnished by the disintegration of the Erie shale has also proved specially adapted to the cultivation of the grape; and most of the vineyards which line the Lake shore from north-east, Pa., to Sandusky, are located on the belt of its outcrops.

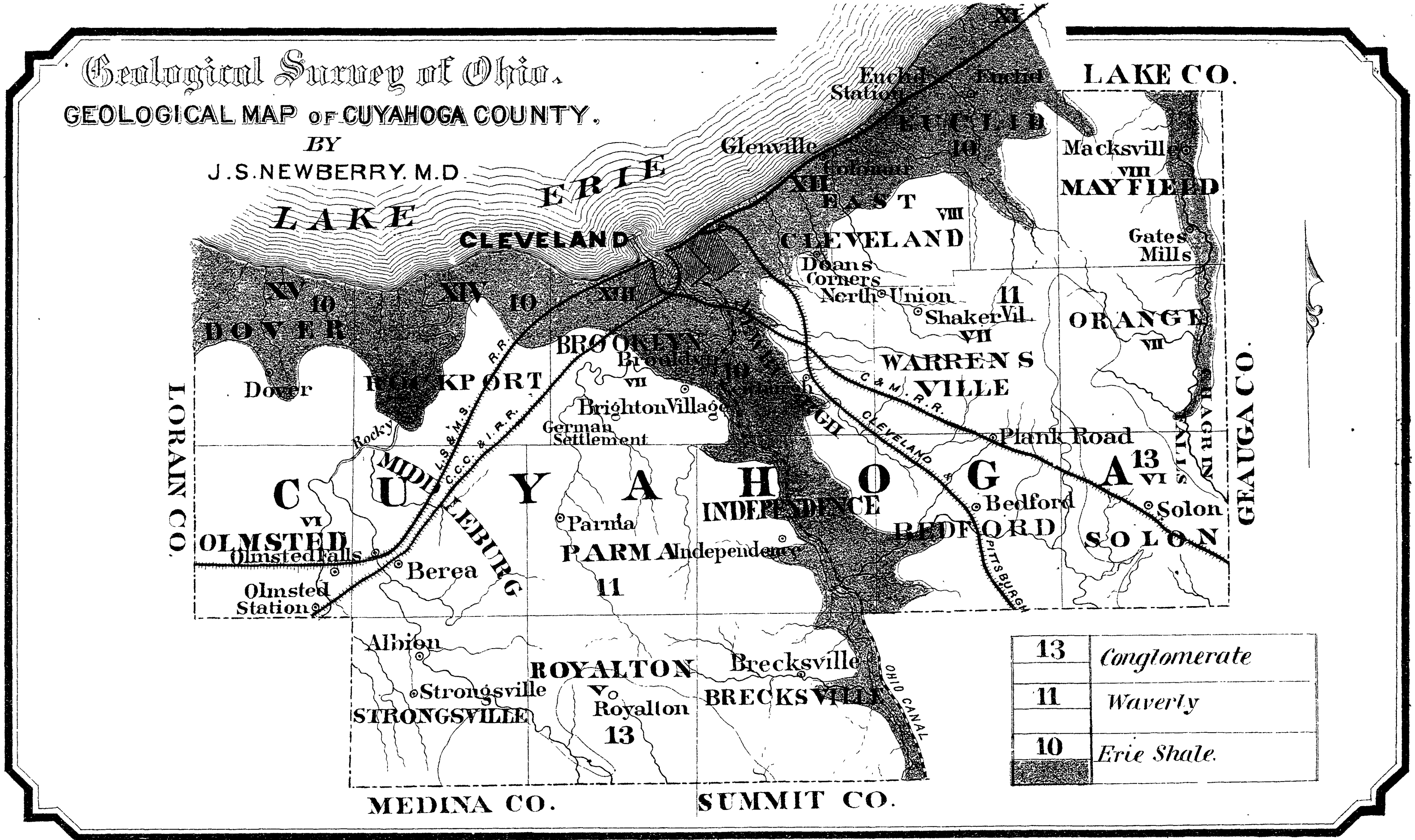
We have now completed the review of the various groups of rocks found in Ohio belonging to the Silurian and Devonian Systems. The features and history of two other great sub-divisions of the geological series which are represented in our state—the Carboniferous and Drift—remain to be discussed. The consideration of these must, however, be deferred for the present, as it will more properly form the introductory and general matter of another volume of this report, which will be for the most part devoted to the local geology and paleontology of these formations. A large amount of new and interesting material has already been collected, which will serve to illustrate the physical and life histories of the great and important geological ages, in which our Carboniferous and Drift deposits were formed; and if we should be permitted to give to the public as full an exposition of the subjects which remain to be treated as we are able to do of those which have been considered, it is probable that they will find the contents of the second volume of the report at least as interesting and valuable as anything contained in this.

GEOLOGICAL SURVEY OF OHIO.

VOL. I.—PART I.

SECTION II.

LOCAL GEOLOGY.



Strobridge & Co. Lith. Cin.

CHAPTER VI.

REPORT ON THE GEOLOGY OF CUYAHOGA COUNTY.

BY J. S. NEWBERRY.

TOPOGRAPHY.

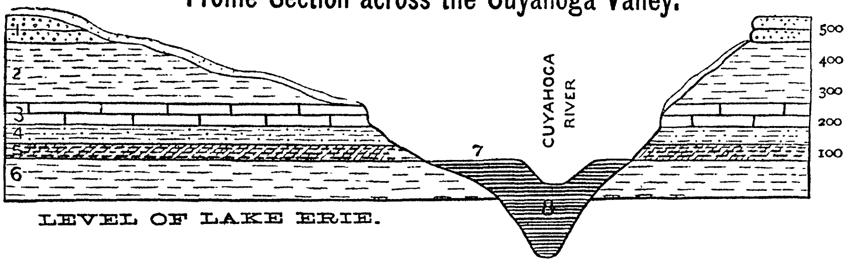
The topography of Cuyahoga County, like that of all Ohio, is without any very striking features and yet it is far from monotonous. The surface configuration is due entirely to the action of erosive agents upon sedimentary rocks which are nearly horizontal. The Lake shore is generally a precipitous bluff or cliff from 50 to 80 feet in height, formed by the action of the waves, which are slowly cutting away the land. Those portions of the shore adjacent to the mouth of the Cuyahoga and immediately west of Rocky River, are composed of Drift materials, which, yielding more readily than the rocky cliffs to erosion, and being more rapidly removed, have occasioned two marked indentations of the coast. The high clay banks found here are softened and undermined by the water so that extensive slides are produced, by which the land area has been considerably diminished within the memory of the present inhabitants. At Cleveland this destructive action has been, over a part of the city front, arrested by piles driven along the beach; but it is known that previous to the adoption of this protective measure, a strip of the Lake shore more than two hundred yards in width had been carried away since the first settlements were made at this point.

The most important topographical feature of Cuyahoga County is the deeply excavated channel of the Cuyahoga, which flows but little above the Lake level from Boston in Summit County to Cleveland. Throughout all this interval the rock bottom of this trough is far below the surface of the Lake; the wells bored at different points showing that the river once ran more than two hundred feet below its present bed. The valley of Rocky River, on the contrary, is, for the most part, a new channel with rocky banks and bottom. Two miles west of the mouth of Rocky River, however, we find what is apparently the former bed of this stream, now filled with Drift—the Erie clay—which here, as at Cleve-

land, extends far below the Lake level. These deep channels, like others of the series to which they belong, were formed at a time when Lake Erie did not exist as a lake, but was represented by a river flowing through some portion of the basin it occupies, and receiving the Cuyahoga, Rocky River, the Chagrin, Grand River, etc., as tributaries at a level two hundred feet below the present mouths of these streams. This was anterior to the first epoch of the Drift period, when the continent was raised several hundred feet higher than now and the drainage was much more complete. Subsequent submergence silted up and often obliterated these old channels with clays deposited from a great body of water which filled all the Lake basin. After this water was partially drained away, and when the rivers flowing from the highlands resumed their functions, they did not always follow accurately their old channels, but sometimes—as in the case of Rocky River—made new ones along the lines of lowest surface levels wherever these happened to run.

The city of Cleveland stands on a plateau of sand, gravel and clay, which occupies the mouth of the old, deeply excavated rocky valley. The surface of this plateau is about 100 feet above the present level of Lake Erie, and marks the height to which the old valley was filled. The tops of the rocky walls of the valley are seen at East Cleveland, Newburg, and Bedford on the east side, at Parma, Independence and Brecksville on the west. They are composed of corresponding strata and here rise from 100 to 200 feet above the old flood plain; at the south line of the county from 300 to 400 feet. By the subsidence of the Lake, the Cuyahoga has made a new valley 100 feet deep through its old delta, but the Lake must be drained away, and the river must cut more than 200 feet deeper into the clays that occupy its old channel, before the rocky floor of the valley will be reached. The following profile section will give a clearer idea of the structure of the Cuyahoga valley than could be gained from description only. It is drawn from the highlands of Orange on the east to those of Royalton on the west.

Profile Section across the Cuyahoga Valley.



1. Conglomerate.
2. Cuyahoga shale.
3. Berea grit.
4. Bedford shale.
5. Cleveland shale.
6. Erie shale.
7. Old Flood plain.
8. Erie clay in old valley.

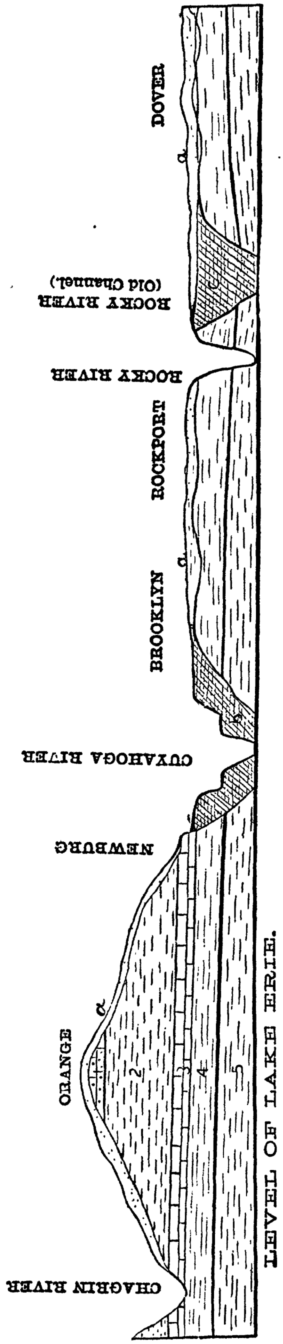
The highest lands in Cuyahoga County rise 550 feet above the Lake. These are projecting points of the great sheet of Carboniferous Conglomerate which underlie the more elevated counties of Geauga, Summit and Medina. These highlands lie in Royalton and Brecksville, west, and in Solon and Orange townships on the east of the valley.

SOIL.

The soil of Cuyahoga County is considerably varied, from the operation of local causes which have broken the monotony so conspicuous in the agricultural character of northern Ohio. This monotony is dependent upon the wide spread of the Drift clays which form the superficial materials. In the southern townships of Cuyahoga County, these clays cover all the underlying rocks, and even over the coarse, porous Conglomerate in Royalton, Brecksville, Solon and Orange, as well as upon the Berea grit in Independence, Parma, Middleburgh, Mayfield, Warrensville and Bedford, form an impervious sheet that has produced a cold and wet soil.

Between the Conglomerate and Berea grit lies a mass of soft gray shale which I have called—because it forms the sides of the valley of the Cuyahoga for many miles—the Cuyahoga shale. This has contributed its quota to the argillaceous matter of the surface, and has probably furnished some of the material that makes up the Drift deposits. From whatever source derived, this surface clay covers almost uninterruptedly the townships which form the high lands of the county. Near the Lake shore, however, we find a belt of soil which is eminently sandy. The sand of this district is derived from ancient beaches which mark the position of the Lake shore when the water level was from a hundred to two hundred feet higher than at present. This sandy area is traversed by two, and sometimes more embankment-like ridges, which have received the name of *Lake ridges*, because they are supposed to be old beaches. They will be more fully described further on. The sand belt exhibits the usual peculiarities of a sandy soil; it is warm, of easy tillage, giving rapid growth and early maturity to fruit trees, but showing both in trees and crops the temporary fertility and early impoverishment which follow its loose and pervious structure. North of the lowest of the ridges referred to above, and fifteen to twenty-five feet below its summit, is a nearly level and somewhat marshy plateau extending to the cliffs which form the Lake shore. From this surface the Drift materials have been washed away, as only a thin clay coating covers the underlying shales. This clay is apparently formed by the decomposition of these shales, as

the soil which it furnishes has somewhat different properties from most of that derived from the Drift clays. This Lake shore belt seems to be specially adapted to the cultivation of the grape, and as Dr. Kirtland has suggested, probably in virtue of the fact that the underlying Erie shales contain a larger percentage of sulphur and potash than do most of the rocks in our geological series. It is in this belt that the vineyards are located which extend from Sandusky to North East.



Profile Section across the Center of Cuyahoga County, from East to West.

a. Drift clay and soil. *b.* Drift clay in Cuyahoga valley. *c.* Drift clay in old valley of Rocky river.

1. Conglomerate. 2. Cuyahoga shale. 3. Berea grit. 4. Cleveland and Bedford shales. 5. Erie shale.

GEOLOGICAL STRUCTURE.

A general view of the geological structure of Cuyahoga County is given in the accompanying woodcut, which is a profile section on a line drawn through the center of the county from east to west. The highlands west of the Cuyahoga are not represented on this section, as they lie too far south. They are shown, however, in the section of the valley of the Cuyahoga given on a preceding page, and a line drawn far enough south to cut the highlands of Brecksville and Royalton, would fail to show the interesting feature of the old valley of Rocky River. The different formations which are represented in the profile section are described in detail in the pages which follow.

DRIFT DEPOSITS.

Erie Clay. I have already alluded to the sheet of clay that so generally covers the rocky structure of the county. This clay was unquestionably deposited from the waters of the Lake when they stood several hundred

feet higher than at present, and it is one of the series of superficial deposits which reach from the highlands 500 feet above the present Lake level to a depth of more than 200 feet below. We know this by the wells which have been sunk in the valley of the Cuyahoga. This is plainly a valley of erosion cut by a stream which for countless ages drained this portion of the southern rim of the Lake basin. In Summit County unbroken sheets of rock form the bed of the river, showing that no rift or fissure has given direction to its flow. At the mouth of the valley, however, no rock appears at the surface, but the trough is occupied by drift clays. In borings made at the shore end of the new Lake Tunnel, the rock was reached at the depth of 78 feet, and at the Crib a depth of 116 feet. At the Engine House of the Water Works—a little nearer the center of the valley—the clay was found to have a thickness of 100 feet below the level of the Lake. At the Rolling Mill near the present mouth of the river no rock was reached at a depth of 100 feet, while at the works of the Standard Oil Company, at the mouth of Kingsbury's Run, a well bored to the depth of 1005 feet passed through 238 feet of Drift clay. The well head is about ten feet above the Lake level. We therefore have evidence that at this point the rock bottom of the Cuyahoga valley lies 228 feet below the present surface of the Lake. The blue clay here reaches up the bluffs that form the banks of the Cuyahoga to a height of about 50 feet above the top of the well. Hence the clay has here a thickness of 280 feet.

The clay to which I here refer is that called by Sir William Logan the *Erie clay*, and is supposed to be the fresh water and interior equivalent of the Champlain clays which were deposited in the earlier portion of the Drift period on the Atlantic coast when it was sunk 500 feet or more beneath the ocean.

The Erie clay may be well seen in the bluffs which form the Lake shore at Cleveland. There the upper 60 feet of the deposit are exposed, and consist of a fine, homogeneous, stratified, blue, sandy clay, without fossils so far as has been observed, and with no pebbles or boulders. In the Lake Tunnel—where it is penetrated about 80 feet lower—it is found to be crowded with small, angular fragments of argillaceous and bituminous shale, evidently derived from the Erie and Huron shales; rocks which were excavated to form the basin of Lake Erie. Occasionally, also, are found in the clay penetrated by the tunnel, rounded, striated boulders, two, three and four inches in diameter, composed of diorite, crystalline limestone, or some other representative of the metamorphic rocks of the Canadian highlands.

The following section of the Erie clay, afforded by the well of Rocka-

feller and Andrews, at the mouth of Kingsbury's Run, will give a good view of the structure of the formation at this point.

Section of Well bored by the Standard Oil Company. Well head ten feet above Lake Level.

		THICKNESS.	
No. 1.	Blue Clay	75 ft.	... in.
" 2.	Coarse Sand	1 "	6 "
" 3.	Blue Clay	27 "	... "
" 4.	Quicksand	... "	10 "
" 5.	Blue Clay	25 "	2 "
" 6.	Quicksand	1 "	6 "
" 7.	Blue Clay	22 "	6 "
" 8.	Quicksand	1 "	... "
" 9.	Blue Clay	30 "	... "
" 10.	Fine Gravel	5 "	... "
" 11.	Blue Clay	29 "	... "
" 12.	Coarse Gravel with much Gas	3 "	... "
" 13.	Fine Quicksand	1 "	... "
" 14.	Blue Clay	5 "	... "
" 15.	Coarse Gravel	2 "	6 "
" 16.	Clay, to the Shale Rock	8 "	6 "
		238 ft.	6 in.

So far as I can learn no fossils have been found in the Erie clay in Cuyahoga County. Land and freshwater shells and drifted trunks of trees have been reported as obtained from this deposit, but I am led to believe that all these have come from the overlying beds.

Partially decayed wood is abundant in the carbonaceous stratum which rests immediately upon the clay, and various fossils have been found in the sand, clay and gravel which lie still higher. By the slipping down of the clay cliffs on the Lake shore, the upper beds of the delta are continually brought down far below their true level, though apparently still in position. These slips have probably furnished all the fossils which have been referred to the clay. This inference is based on my own complete failure in years of search to find any traces of fossils in this formation. It is but fair to say, however, that this evidence is only negative, and that Mr. M. C. Read reports finding a water worn fragment of wood in the Erie clay of Lake County.

An analysis made by Dr. Wormley of a specimen of the Erie clay, furnishes the following result:

Analysis of Erie Clay.

Water	4.00
Silicic Acid	59.70
Alumina	14.80
Iron, Sesquioxide	4.60
Lime, Carbonate	8.90
Magnesia	5.14
Fixed Alkalies	3.40
	100.54

Delta Sand. Above the Erie clay we have about Cleveland a thickness of about 25 to 50 feet of sand, gravel and clay, mostly coarse and porous material, differing greatly in appearance from the underlying bed. This stratum, or group of strata, is intimately associated with the Lake ridges and belongs to the same geological period. I have called it the *Delta sand deposit*, because it is composed of sand and gravel evidently washed down from the area drained by the Cuyahoga, and deposited in the comparatively still water at its mouth. Similar deposits, or the continuation of this one, stretch around the margin of the Lake, most conspicuously developed at the mouths of the rivers. The Delta sand deposit is separated from the underlying clay at some localities about Cleveland by a distinct band of carbonaceous matter from one to two feet in thickness, where large numbers of tree trunks are found buried. This timber is not fossilized, but has undergone some change from its original condition. All I have seen of it is of coniferous character, and apparently pine or spruce. A similar sheet of carbonaceous matter extends very widely through the Drift deposits of Ohio and other western states, and marks a distinct period in the Drift epoch; one of great interest in the series of changes which make up this somewhat tempestuous history. It is apparently the record of a time when a large portion of our western states was covered, not by ice as before, nor by water as afterwards, but by a forest growth which continued long enough to produce an accumulation of carbonaceous matter on the surface; in other words, a soil. In this soil we find great numbers of prostrate trunks and occasionally standing, rooted trees. To distinguish this ancient soil I have called it the *Forest Bed*; and of this we have perhaps traces in the carbonaceous stratum so conspicuous in the clay cliffs at Cleveland.

The accumulation of Drift material filled the valley of the Cuyahoga to something more than 100 feet above the present level of the Lake, and, as has been stated, the city of Cleveland is built upon a portion of the delta of the Cuyahoga. If the valley of this river had been less broad and deep, it would have been entirely obliterated by the Drift de-

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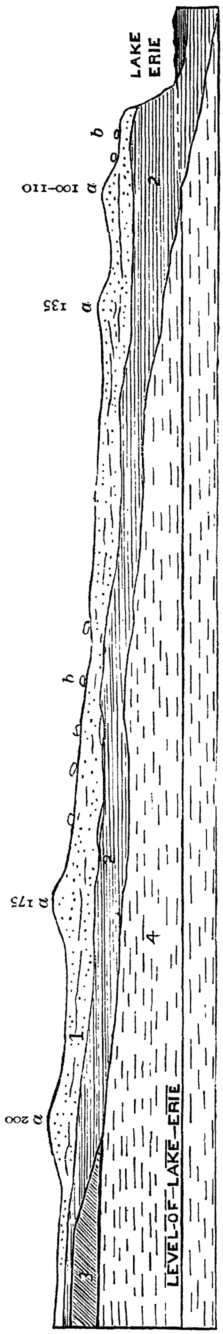
posits. In that event the Cuyahoga would very likely have chosen some other route when, by the withdrawal of the water that submerged all this region, it resumed its function of a draining stream to what are now Geauga, Portage and Summit counties. I am led to believe that precisely that which I have imagined of the Cuyahoga happened in reality at Rocky River, as has been already suggested. Parallel instances are not uncommon, and that of the Genesee at Portage, N. Y., cited by Prof. Hall, is apparently identical in character with this one. The immensity of the interval of time that has elapsed since the old valley was filled, is indicated by the depth to which the new valley of Rocky River has been excavated. This is less broad and deep than that of the Genesee at Portage, but it is such as could only have been formed in a much longer period than has been allowed to the great lakes by those who have attempted to make them measures of time.

Lake Ridges. The ridges which traverse the Lake shore in Northern Ohio have already been referred to, but they form such a peculiar and interesting feature in the surface geology, that they seem to require some further description. In Cuyahoga County the Lake ridges occupy only a portion of the narrow belt which lies between the present Lake shore and the highlands. They are here less notable features in the surface topography than further west, where the country is more level and monotonous. There they are more widely separated, more distinctly marked, and are traceable in nearly unbroken lines running imperfectly parallel with the present Lake margin, at different elevations and distances in the interior, around to the Michigan line. In many localities they have the appearance of railroad embankments, are generally followed by the county roads, and as "Lake ridges" are well known to all the inhabitants. They have received this name from their obvious relation to the Lake shore, and from a general conviction that they are ancient shore lines. I shall elsewhere endeavor to show that this conviction is based on truth, and that each of these ridges marks a period of arrest in a progressive depression of the Lake level. West of the Cuyahoga river, two principal and several intermediate ridges may be traced. On the east side of the Cuyahoga, the highlands approach so near the Lake that generally only the lowest and most northerly ridge of the series is visible on the low ground which borders the Lake. The line of the higher ridges is here perhaps marked by the terraces on the slope of the highlands. The plateau on which Cleveland stands, rising to the height of but little more than 100 feet above the Lake, catches only the lowest of the series. This is, however, distinctly marked, traversing the city on the north side of Euclid Avenue, passing along the south side of Monu-

ment Square and terminating abruptly on the bluff which formerly overlooked the river near the foot of Superior Street. West of the river it was resumed with equal abruptness; beginning on the top of the bluff above the Cuyahoga Steam Furnace, thence extending continuously to the gorge of Rocky River; beyond which it reaches to and far beyond the county limits. This ridge has an average altitude of 100 feet above the Lake; its surface varying from 90 to 110 feet. It is generally composed of clean sand above, and often throughout its entire mass. In other localities it is formed of water-washed gravel, and in places, has rather the aspect of a terrace than a ridge. South of the north ridge, the almost perfectly level surface of the Cleveland plateau bears many low sand knolls, and several local and broken ridges, but it is so low that the lines of the higher ridges pass above it. The positions and altitude of this ridge on the west side of the Cuyahoga will be seen by referring to the accompanying profile, which is drawn from a point on the Lake shore near the new tunnel, southward through the suburbs of the city. On this profile section, four ridges are represented, of which the first is the one already described.

Lake Ridges in Cleveland, West Side.



1. Delta sand, clay, and gravel. 2. Drift clay, stratified. 3. Cleveland shale. 4. Erie shale. *a, a, a, a.* Lake ridges. *b, b.* Boulders of granite, etc.

The second ridge, two hundred yards south of the first, has an altitude of 135 feet. A street has been recently opened through this ridge which shows that it is composed of coarse gravel above, of finer gravel, interstratified with sand, below.

The third ridge is that cut through by the C. C. & C. Railroad. Its surface has an average altitude of 175 feet. Where intersected by the railroad it forms a symmetrical embankment, sloping regularly each way, having an altitude above its base of 25 feet, and a

diameter of about 100 yards. It is mainly composed of fine gravel, and is locally capped with sand. This ridge terminates abruptly on the banks of Big Creek, about one mile above Brighton.

The fourth ridge, half a mile south of the third, has an altitude of 200 feet above the Lake. This is also composed of gravel, with many small, rounded, but not striated, boulders of granite. A large part of the gravel of this ridge consists of fragments of the harder layers of the Erie and Cleveland shales, all rounded and water worn. From the lamination of the shales, most of the fragments are flat and thin, and they are generally found resting on their flat sides. There is comparatively little clay or sand in either of the higher ridges, and they seem to be composed of material washed and sorted by water, which removed all of the finer particles. No good opportunity is now afforded for examining the structure of these two ridges, but so far as it can be observed, it shows the action of water, and everything indicates that they were raised, mainly through the agency of shore waves. The structure of the lower two ridges is more fully exposed, and proves them to be Lake beaches; apparently just such as are now forming around the south shore of Lake Michigan. Of the ridges I have described, the highest and lowest are continuous from the Cuyahoga eastward to the Pennsylvania line, and they apparently extend westward, sweeping around parallel with the Lake shore, to the line of Michigan.

The granitic boulders represented at *b. b.* on the profile, are sometimes quite numerous *between* the ridges, but I have never seen one *on* either of the ridges in Cuyahoga County.

The origin and mode of formation of these Lake ridges will be found more fully discussed in the chapter on Surface Geology than it can be here, but before leaving the subject I will briefly refer to two theories of their origin which have been published; both of which seem to be untenable. The first of these is that they are subaqueous bars, such as form off the mouths of rivers, &c. In my judgment their continuity in lines of 100 to 200 miles in length, their remarkable uniformity of level—especially that of their bases—and the coarseness of the materials which sometimes compose them, afford conclusive arguments against this view. The second theory regards them as moraines raised by glaciers, but it is not difficult to demonstrate that they belong to an age long subsequent to the Glacial epoch, and that ice, unless in sheets floating on a water surface, could have taken no part in their formation. I will briefly allude to some of the facts with which, as it seems to me, the glacial theory of the Lake ridges is incompatible.

1st. The uniformity of level of the ridges is such as is not exhibited

by any known moraines. A water surface is always level, and a shore line is necessarily horizontal; but neither the bottom, top nor edge of a glacier shows any regularity of level. The horizontality of the Lake ridges make them contour lines on all irregular surfaces—precisely as all water lines are—and their parallelism among themselves and with the present Lake shore, indicate that they too are shore lines.

2d. They are of a very modern date as compared with the Glacial epoch. In Cleveland the lowest and latest formed of the Lake ridges, rests upon the summit of all the Drift series, and is separated from the glaciated rock-surface by 300 feet of stratified clay and sand, containing near the top the bones of the elephant and mastodon. The Glacial epoch was anterior to the date of the deposit of the lowest and oldest stratum of the Drift, while the ridges were raised subsequent to the deposition of the highest and last.

3d. The fact that the lowest Lake ridge is, in places, underlaid by 300 feet of soft stratified clay, shows conclusively that no great glacial ice-mass pushed its component materials into the positions they now occupy. No glacier could have raised the ridge without breaking up and removing the stratified beds of the delta below.

4th. The structure of, at least the lowest ridge, and the materials which composes it—sand and gravel—such as form the surface of the delta of the Cuyahoga, often stratified and containing sticks and leaves, teaches the same lesson.

5th. On abruptly sloping surfaces the ridges are replaced by terraces; which confirms the view that they mark old shore lines, and refutes the theory that they are moraines.

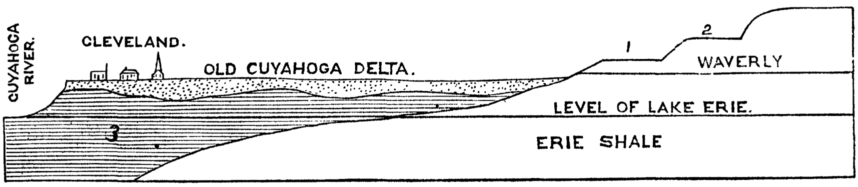
Although, as compared with the glaciers, the Lake ridges are very modern, they may be shown to have a very considerable antiquity. On the banks of Rocky River, they are found to terminate abruptly at the gorge, and to form lines on either side, of which the bearings are unchanged, and the continuity is broken only at this point. Hence we may infer, that when the ridges were formed, the gorge had no existence; that they were then continuous, and that the river has cut through them, and has worn its channel to the depth of more than 100 feet in the Erie shale since the date of their formation.

Terraces. The eastern slope of the Cuyahoga valley is marked by two very distinct terraces, which may be traced continuously from East Cleveland to Newburg. The first and lowest of these terraces has an altitude of from 165 to 170 feet above the level of the Lake. It is underlaid by the Cleveland shale which is partially cut away. The surface, in some places, as near East Cleveland, is formed of clean fine sand, but

usually the rock is covered by a comparatively thin sheet of clay. The next terrace is about fifty feet higher than the last, or 210 to 220 feet above the Lake. This is floored by the sandy layers of the Bedford shale, such as are quarried at East Cleveland. On this terrace the rock is usually covered with four or five feet of clay. The old Kingsbury house stands on this terrace. The next plateau is formed by the Berea grit, and is the summit of the highlands immediately overlooking the valley. The surface of this plateau seems to the eye nearly level, but it gradually rises eastward through Warrensville to Orange, where it is underlaid by the Conglomerate and has an altitude of 550 feet above the Lake.

The subjoined wood cut will perhaps aid in obtaining a clear idea of the relative positions of these terraces.

Terraces East of Cleveland.



1. First Terrace, 165 feet above the Lake.
2. Second Terrace, 210 feet above the Lake.
3. Drift deposits forming the old Delta of the Cuyahoga and filling the old valley.

The terraces I have described do not correspond in altitude with the ridges which mark the more gentle slope of the western side of the valley, yet it is hardly possible to avoid the conclusion that they are old shore lines, and that they mark successive steps in the descent of the surface level of the Lake. If this is their history, we can readily imagine that the lower one, with an altitude of 165 to 170 feet, may have been formed at the same time with the highest of the ridges on the opposite side of the valley; namely, that which has a surface altitude of 200 feet. It should be remembered that a terrace is cut by shore waves somewhat below the water level, while on a gently inclined surface of loose material the waves raise a beach above the water. The base of the highest ridge on the west side of the Cuyahoga corresponds very closely in altitude with the surface of the first terrace. When the water in the Lake stood high enough to cut the second terrace, it must have swept over all the country lying between Berea and Cleveland, and the shore line must have run along the base of the highlands of Parma, Independence and Brecksville. The outcrop of the Berea grit at Independence evidently once formed abrupt, often perpendicular shore cliffs. Above this point the soft Cuyahoga shale, 200 feet in thickness, forms a

slope, on which, from the nature of the materials, shore lines, however distinctly marked, would be soon obliterated. In Cuyahoga County no Lake ridge has yet been detected higher than those already described; but this is probably due to the nature of the surface; for in Lake County, the highest ridge of the series has an altitude of 250 feet above the Lake. This would indicate a water level nearly identical with that recorded on the upper terrace of the Cuyahoga valley.

Surface Boulders. The boulders of granite, greenstone, &c., which strew the surface in many parts of Cuyahoga County, have attracted the attention of most observing persons. They are often of many tons weight, and are, in some localities very numerous. On one of the slopes of the highlands between East Cleveland and Euclid, is a field so thickly strewn with them, that in the distance they resemble a flock of sheep, scattered over a pasture. Composed as they are of rocks nowhere found in place in the state of Ohio, and traceable to sources north of the great lakes, they have given rise to much speculation as to how they could have been transported to their present resting places. The solution of the problem, however, seems to me not difficult. They are found only on or near the surface, often resting on stratified Drift clay of great thickness. It is plain that they never could have been transported by glaciers, and *pushed* into their present condition. They form, therefore, no part of the *glacial* Drift. Neither could currents of water have transported them without tearing up and washing away the underlying clays. Hence, they must have been *floated* from the far north, and dropped from the floating agent into their resting places. No other agent than floating ice seems capable of effecting their transport, and we are driven to the conclusion that they were scattered by icebergs, just as gravel and boulders are now being spread over the Banks of Newfoundland. In the chapter on Surface Geology the origin and transport of these erratic blocks will be more fully discussed, and the reasons will there be given why I attribute these and other materials which constitute the last deposits of the Drift, to the agency of icebergs, and call them the *Iceberg Drift.*

The fossils of the superficial deposits are not numerous. Coniferous wood occurs at the top of the Erie clay; the clay itself having, so far as I can learn, no fossils. The Delta sand deposit—that is, the gravel and sand which form the surface of the Cleveland plateau—has yielded numerous portions of the skeletons of elephant and mastodon. In other parts of Ohio these are found in the Forest-bed and in the overlying portion of the Drift; as well as in the peat marshes that belong to the present geological epoch. Hence we may conclude that the elephant and

mastodon continued to inhabit portions of what is now Ohio from the time when the ancient soil to which I have referred, accumulated. But all of Cuyahoga County was deeply submerged subsequent to that period, and we therefore here find those remains only in the delta of the river when it flowed at a higher level than now, and floated them down from the highlands southward.

CARBONIFEROUS SYSTEM.

The rocks underlying the Drift in Cuyahoga County represent two great divisions of the Carboniferous, and the uppermost member of the Devonian system. The section afforded by these rocks is as follows:

			THICKNESS.
1.	Carboniferous Conglomerate		100 ft.
2.	Cuyahoga Shale	Waverly Group.	150–200 "
3.	Berea Grit,		60 "
4.	Bedford Shale,		75 "
5.	Cleveland Shale		21–60 "
6.	Erie Shale (Devonian) to Lake		100–150 "

These strata may be said to be, in a general way, horizontal, but in fact, except where cut by the valleys of the rivers, they form continuous sheets that lie in a series of long and gentle undulations. The prevailing dip of all the rocks of this portion of Ohio is towards the south and east, but any one who will take the trouble to sail from Cleveland to the mouth of Rocky River will see that in the western half of this interval the Erie shales dip westwardly 60 feet; that is, 20 feet to the mile. So the Berea grit, of which the base at East Cleveland is 228 feet above the Lake level, at Berea lies more than 60 feet lower, as its upper surface is only 220 feet above the Lake. In Lorain county this rock descends a hundred feet lower still.

CARBONIFEROUS CONGLOMERATE.

The Conglomerate, as has been stated, is found only in the higher portion of the County. There it forms the salient angles of the great plateau which occupies so much of the counties of Geauga, Summit and Medina. A point of the Conglomerate reaches into Cuyahoga County from the south on the west side of the Cuyahoga in Royalton and Strongsville, and another in Solon and Orange on the East. The base of this formation is 450 to 500 feet above the Lake. The rock itself is a coarse sandstone, locally containing—especially toward the base—such quantities of quartz

pebbles that they constitute nine-tenths of its mass. Rock of this character may be seen on the road from Solon Station to Chagrin Falls; also near Plank-road Station, on the west side of the valley of the Chagrin. These quartz pebbles may hereafter be utilized for the manufacture of porcelain, for peculiarly refractory fire bricks, or for some others of the many purposes served by pure silica.

WAVERLY GROUP.

These are the rocks which form what was designated by the first Geological Corps as the "Fine-grained sandstone" or "Waverly" series. For a long time it was supposed that they were the equivalents of the Chemung and Portage groups of New York; but those are now known to be represented by the underlying Erie and Huron shales; and the Waverly has been shown by the investigations of the present Corps to be of Carboniferous age.

In southern Ohio the Waverly group consists largely of ochery sandstones and shales, and is much more homogeneous than in the northern part of the state. In Cuyahoga County it is composed of a variety of strata, to each of which, for convenience, a distinct name has been given. These beds have been already enumerated, and they will now be described in the order of their occurrenee.

CUYAHOGA SHALE.

This is the uppermost member of the Waverly group, and consists mainly of gray argillaceous shale with thin flags of fine sandstone scattered through it. Its outcrop forms a belt extending from Berea, where it caps the Berea sandstone, around through Parma and Independence into the valley of the Cuyahoga, of which it forms the immediate banks on both sides as far southward as Cuyahoga Falls. In the eastern part of Cuyahoga County it is the surface rock in much of Bedford, Warrensville, Orange and Mayfield.

Throughout this area the Cuyahoga shale is rather an uninteresting and comparatively valueless formation. It holds no useful minerals, and in its decomposition gives rise to a soil which is tenaceous, cold and difficult to work. It is also generally barren of fossils, and yet at certain localities, as at Berea and Chagrin Falls, it contains a few species in immense numbers. In both these places that portion of the Cuyahoga shale which immediately overlies the Berea grit contains myriads of *Lingula melia* and *Discina Newberryi.* With these are a few scales of *Palaconiscus*, a Carboniferous ganoid, and teeth of *Cladodus*, a Carbonifer-

ous shark. In Summit and Medina counties the Cuyahoga shale is exceedingly fossiliferous; and certain localities — such as Richfield, Medina, Weymouth, Bagdad, &c.—furnish larger lists of species than perhaps any others known in the state. Catalogues of the fossils of the Cuyahoga shale will be more properly introduced in the reports of the geology of the counties I have referred to.

BEREA GRIT.

Below the Cuyahoga shale lies a well known stratum, which, from the locality that has rendered it most famous, I have called the Berea grit. This is a bed of sandstone something like 60 feet in thickness, varying much in character in different localities, but possessing qualities that render it one of the most valuable formations in our entire geological series. Compared with the Conglomerate, the Berea stone is much finer and more homogenous in texture. It very rarely contains any pebbles in this section of the state, though further south it is sometimes in part a coarse Conglomerate. It is in fact a typical grindstone grit, and is the source from which the greater part of the grindstones now sold in our country are derived.

The color of the Berea grit differs in different localities. At Berea some of the layers are nearly white, and the prevailing tint is gray. At Independence, Chagrin Falls and Amherst, it is a light buff or drab. These differences of color, are in a large degree due to local and appreciable causes. At Berea the stone is quarried below drainage where it is covered by a portion of the Cuyahoga shale and by Drift clay; while at Independence, Bedford and Chagrin Falls, as at Amherst, it lies higher and is more thoroughly drained. In the latter localities atmospheric water has been for ages freely passing through the rock, and has thoroughly oxydized whatever iron it contains; whereas at Berea it is buried or submerged; oxygen is excluded and the iron contained by the grit is in the condition of protoxide or sulphide.

The outcrop of the Berea grit is concealed in most parts of the county, but it has been so carefully traced that we are now able to indicate the exact line it follows. From Olmstead Falls and Berea it passes nearly eastward, and is concealed by the overlying clays till it crosses the road leading from New Brighton to Parma. Thence it sweeps around into the valley of the Cuyahoga, forming at Independence bold bluffs in which the quarries are located. These bluffs were unquestionably once the shore cliffs of the Lake, and anterior to that time the stratum of the Berea grit stretched across the valley of the Cuyahoga, probably forming a shelf over which the river flowed in a cascade rivalling in

height, if not in volume of water, that of Niagara. In the course of ages this shelf was cut away; the falls being gradually carried back to a point beyond Boston in Summit county, where the Berea now forms the bed rock of the river. The Berea grit is a distinctly marked stratum in the cliffs or banks on both sides of the Cuyahoga from the Peninsula to Independence on the west, to Brandywine Mills and Bedford on the east. Thence it follows around the highlands through Newburg, East Cleveland and Euclid, and passes up the valley of the Chagrin to the Falls. In tracing this long line of outcrop we find that the Berea grit exhibits considerable differences both in texture and structure. It may be said, as a general rule, that the upper 20 feet are much more shaly than the lower portion; which is often quite massive, furnishing building stone of any desired dimensions. In some localities—as at Chagrin Falls and Bedford—a stratum of shale is interposed between the two divisions.

Like most sandstones, the Berea grit contains comparatively few fossils, yet these few are of special interest. At Bedford, the surface of some of the layers is completely covered with stems set with the verticils of leaves of a species of *Annularia* scarcely distinguishable from *A. longifolia* of the Coal Measures. In the upper portion of the Berea, at Chagrin Falls, the quarries of Mr. H. Goodale have furnished a large number of fossils fishes, but all of one species—*Palaeoniscus Brainerdi*—a rhomb-scaled ganoid allied to the gar-pike, but much smaller. From Berea I have obtained fragments of the bones of much larger fishes, but none complete enough for description; also a few shark's teeth, (*Cladodus*) and a large species of *Lingula*—(*L. Scotica?*)

The economic value of the Berea has been already referred to. It constitutes the basis of all the great business done at Berea and Independence, in Cuyahoga County, and at Amherst, Lorain County. At Berea more than 500 men are employed in and about the quarries; and the value of the annual production is nearly $500,000. During the year 1870 there were taken from the Berea quarries 9,945 car loads of stone of the several varieties produced there. These are mainly "flagging," which sells at 8 cents per square foot; "clear rock," at 30 cents per cubic foot, and grind stones of which the price is from $12 to $15 per ton. Both the building stone and the grind stones from the Berea quarries are now exported to all parts of the Union. In New England, the Berea grindstones compete successfully with those from Nova Scotia, while the building stone is being extensively used, and for some of the most expensive and beautiful structures in all the cities of the northern states.

The following is a list of the firms by whom the stone business of Berea is transacted:

McDermott & Co.
The Diamond Quarry Co.
E. W. Ensign.
Lyman Baker & Co.
F. A. Stearns.
The Owen Stone Co.
C. W. Stearns.
W. R. Woods & Co.
C. McDermott.
(the latter at Lake Abram.)

At Independence the stone has a warm tint from the oxydation of its iron, and has a coarser grain than that at Berea. It is extensively quarried here for both building and grindstones. The grindstones made from the Independence rock are generally of the largest size and are best adapted to dry grinding. About 5,000 tons of grindstones were produced by the Independence quarries last year. From a want of uniformity in texture and color in the Independence rock, the building stone requires to be selected with care; but when so selected, is not excelled in beauty or durability by that of any other outcrop of the formation.

The Berea grit is seen in the hills near East Cleveland, and is the rock taken out at Stewart's quarry, as well as that exposed at the Shaker Mill and at the falls of Euclid Creek. In this region the stone is less desirable in texture and color than where it appears on the west side of the Cuyahoga. The same may be said of the lower portion of the Berea, over which the water pours at Chagrin Falls. The upper layers here furnish excellent flagging and are quarried for this purpose.

BEDFORD SHALE.

The Berea grit is usually underlaid by a red shale, so bright in color as to be quite noticeable at all its outcrops. It therefore often serves as a good guide in searching for the quarry stone. This shale is seen overlying the "blue stone" quarried in East Cleveland, above the Kingsbury quarries, at several places in Newburg and Bedford, and on the west side of the Cuyahoga at most of the outcrops of the Berea where the stratum is penetrated to its base. In some localities, however, as in the gorge of Tinker's Creek at Bedford, no red shale is visible. Beneath the Berea sandstone at this last mentioned point we find 70 feet of *blue* shale. These differences of color are dependent simply upon the quantity of iron contained in the rock, and its condition of oxydation. Another phase still is exhibited at the Newburg, Kingsbury and East Cleveland quarries. Here a mixture of fine sand has converted the lower portion of the Bedford shale into a blue fine-grained sandstone. This is the "blue stone" of the Cleveland market; a fine, compact and serviceable stone, but it contains considerable iron in the condition of sulphide. This is liable to

oxydation on exposure, and therefore tends to produce stains and sometimes decomposition. It is, however, extensively used for flagging, and when sawed makes one of the best and handsomest flagging stones in the country. It is the precise geological equivalent of the "Buena Vista stone" of the Scioto valley, now so largely used in Cincinnati and New York, and is in no respect inferior to that. About 50,000 square feet of sawed flagging are now furnished each year by Messrs. Bruggeman & Keck, at their quarries in East Cleveland, and a large amount is also produced at Newburg.

The best exposure of the Bedford shale is at Bedford, and it has received its name from this fact. Here the lower portion of the stratum is highly fossiliferous, containing several species of mollusks represented by a large number of individuals. Of these, the most conspicuous is *Syringothyris typa*, a large Spirifer-like shell, first described by Prof. Winchell, State Geologist of Michigan, and now recognized as one of the most characteristic fossils of the Waverly. With this are *Rhynchonella Sagerana, Orthis Michelini, Spiriferina solidirostris, Macrodon Hamiltoniae?* etc.

CLEVELAND SHALE.

This name has been given to the black bituminous shale found in most of the counties of the Reserve, from the Vermillion River to the Pennsylvania line. In this distance it varies in thickness from 20 to 80 feet, but in Cuyahoga County it may be said to vary from 21 to 60 feet. This rock is well shown in the valley of Rocky River, in the gorges of the streams at Newburg and Bedford, and below the Kingsbury and East Cleveland quarries; also in the streams running northward, in the eastern part of the county. It is usually a highly bituminous shale, containing 10 to 15 per cent. of combustible matter, and it is an interesting fact that over the outcrop of this bed we have a distinctly marked line of oil springs; among which may be mentioned those of Mecca, Trumbull county, East Cleveland, Grafton and Liverpool. There is little doubt that the petroleum noticed at so many places along this horizon is derived from the slow distillation of the underlying Cleveland shale.

The fossils of the Cleveland shale are not numerous or varied, yet it is not as formerly supposed, entirely unfossiliferous. At Newburg this rock forms the precipice over which the water flows at the falls, and scarcely a fragment of it can be found which which does not contain scales of fishes. At Bedford I obtained from this stratum quite a number of fish teeth consisting of species of *Polyrhizodus, Cladodus* and *Orodus;* all Carboniferous sharks. The surfaces of the shale are also in this locality, sometimes covered with little comb-like fossils described by Pander, the Russian palacontologist, under the name

of *Conodonts*, and supposed by him to be the teeth of small sharks. These, I think, will prove to be dermal ossicles of cartilaginous fishes, and to be most nearly allied to the shagreen that covers some portion of the surface of the sturgeon.

The following analysis of a specimen of Cleveland shale, from the gorge of Tinker's Creek at Bedford, has been made by Prof. Wormley:

Water	1.10
Earthy matter	87.10
Volatile matter	6.90
Fixed carbon	4.90
	100.00
Gas per lb	0.62 cu. ft.

DEVONIAN SYSTEM.

ERIE SHALE.

The Cleveland shale is the lowest member of the Waverly formation, and the base of the Carboniferous series. It is underlaid by shale, which, within fifty feet, contains well marked Devonian fossils. To this latter formation I have given the name of *Erie shale*, because it forms the shore of Lake Erie nearly all the way from the mouth of the Vermillion to Dunkirk. Until recently these shale beds were supposed to be the equivalents of the Portage group in New York, while the Waverly above was regarded as the western prolongation of the Chemung. By the discovery of numerous fossils we have been able to set this much debated question at rest, and show conclusively that, while the Erie shale is Devonian, the Waverly strata above are Carboniferous. In the gorge of Tinker's Creek near its mouth, in that of Chippeway Creek, on the west side of the Cuyahoga, in the valley of the Cuyahoga itself in Northfield, and at various points in Lake and Ashtabula counties, we have obtained from this formation fossils which demonstrate its relation to the rocks of New York and Pennsylvania. These fossils are *Leiorhynchus mesacastalis*, *Orthis Tioga*, *Spirifer Verneuili*, *Spirifer altus* and some others, all of which are characteristic fossils of the Chemung.

The Erie shale also contains the representative of the upper, or more sandy portion of the Portage group of New York, which, like all the other mechanical sediments of the series, thins out toward the west and becomes more argillaceous in composition. In western New York and Pennsylvania, the strata which here form the Erie shale have a thickness of perhaps 2,500 feet. In Cuyahoga County they have diminished to 400 or 500 feet, and in Huron County thin out and disappear.

The lithological character of the upper part of the formation is well shown upon the Lake shore, both east and west of the mouth of the Cuyahoga. From the Lake level up 100 to 150 feet,—according to the relative elevation of the overlying rocks,—we find a mass of gray and blue argillaceous shale containing sheets of micaceous, pearly sandstone, and lenticular nodules of iron ore. These strata form the cliffs between Cleveland and the mouth of Rocky River, where they are seen to have a rapid dip westward. The lower portions of the formation, as we learn from numerous borings, are more or less interstratified with the upper layers of the great black shale bed, known at the west as the *Black slate*, and which next claims our attention.

HURON SHALE.

The Erie shale rests on the thick bituminous stratum which has been referred to, and which we now designate as the *Huron Shale.* This in turn is underlaid by the Hamilton and Corniferous limestones, which crop out at Sandusky. Neither of these three formations come to the surface in Cuyahoga County, and they might be omitted from a sketch of its geology, except that it will be, perhaps, interesting and useful to the residents of the county, to know what rocks lie immediately below those exposed here. The Huron shale also deserves notice from the fact, that it is undoubtedly the source from which petroleum emanates in such abundance in western Pennsylvania, and the gas that rises from springs and wells at various points along the Lake shore. The Huron shale apparently represents, in Ohio, the lower and more bituminous portions of the Portage group, and the underlying bituminous stratum, called by the New York geologists, the Genesee slate. It will be found fully described in other portions of this volume, and I will only say in passing that it rises to the surface at Avon point in Lorain county, and in that vicinity has yielded some of the most remarkable remains of fishes found fossilized in any part of the world.

The Erie and Huron shales undoubtedly once occupied all the basin of Lake Erie, and stretched across, in unbroken sheets, to the base of the Canadian Highlands. From their soft and yielding nature they offered little resistance to the excavating action of the great glacier that once filled the Lake basin. We find the Drift clays which cover so much of the south shore of the Lake, filled with, and sometimes largely composed of fragments of these shales; and the upper and finer portions of these clays are probably formed of the same material, in a more perfectly comminuted condition. Hence we may consider the clay soil which covers so much of northern Ohio as in large part derived from the Huron and Erie shales.

GAS WELLS.

The gas springs to which I have alluded as occurring along the Lake shore, are now attracting considerable attention on the part of our citizens, as a possible source of supply of material for lighting and heating. Gas springs are generally found along the lines of outcrop of bituminous rocks, and a series of them may be traced, running parallel with the belt of exposure of the Huron shale, or its equivalents, from central New York westward to the mouth of the Huron river, and thence southward through Ohio and Kentucky. These gas springs are apparently due to fissures opened to the gas producing rock below; fissures usually traversed by streams of water, through which the gas rises in bubbles. One of the most copious of these gas springs, at Fredonia, New York, attracted attention in the earliest settlement of the country. The flow of gas from this source has been utilized, and for more than forty years has served to light the town.

Carburetted hydrogen escapes from the ground at numerous points in Cuyahoga County, and one of these gas springs, near the brickyard, above the toll-gate in East Cleveland, has been visited by most of the inhabitants of the surrounding district. At Erie, Ashtabula, Painesville, and at other points on the Lake shore, successful efforts have been made to obtain a supply of illuminating gas, by boring wells expressly for this purpose. Several wells have also been bored for gas in the vicinity of Cleveland, but so far, with not the most satisfactory results, and it becomes a question of much practical importance to determine whether the success which has been met with elsewhere will attend such efforts here. The geological formation is the same in Cleveland as at Erie, but, judging from all the trials that have yet been made, I am inclined to believe that wells sunk for gas in Cuyahoga County, will not yield so large a quantity as those bored further eastward. The influences that control the escape of carburetted hydrogen from the bituminous strata, seem to be the same as those which regulate the flow of petroleum. The origin of the two hydro-carbons is the same, and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks. The source of the petroleum and the abundant flow of gas with which it is associated on Oil Creek, the gas and less abundant petroleum of Erie and other points on the Lake shore, is undoubtedly the Huron shale; and we must look to the physical condition of this and the associated strata, for an explanation of the great variation in productiveness which they exhibit in different localities. This question will be found more fully discussed in other portions of our geological reports, and I will only

say here that the facts I have observed lead me to conclude that the disturbed condition of the strata in certain districts east of Ohio, is the cause of the phenomena which they present. Where the oil and gas producing rocks, and those overlying them, are solid and compact, decomposition of the organic matter they contain takes place very slowly, and the escape of the resulting hydro-carbons is almost impossible. Where they are more or less shaken up, decomposition takes place more rapidly; reservoirs are opened to receive the oil and gas, and fissures are produced which serve for their escape to the surface. Near the Alleghanies all the rocky strata are more or less disturbed, and here along certain lines, the liquid and gaseous hydro-carbons are evolved in enormous quantities. As we come westward, however, we find the rocks more undisturbed, and the escape of oil and gas, through natural or artificial orifices, gradually diminished.

The number of wells bored yet in the vicinity of Cleveland, can hardly be said to have decided the question as to whether the promise of success is sufficient to warrant the necessary expenditure. Two wells have been bored within the limits of the city, one by the Gas Company, near the mouth of the river, the other by the Standard Oil Company, at the mouth of Kingsbury's Run. Both of these have yielded gas, but not in large quantity. Another well has been bored by Captain Spaulding, between Cleveland and Rocky River, from which a sufficient amount of gas escapes to light several houses. The result of this latter experiment has been regarded as so encouraging, that other efforts of the kind are about to be made in the vicinity. A very copious flow of gas issues from a well in the valley of Rocky River, and it is evident that there are localities in and about Cleveland, where gas may be obtained in large quantities by boring. Unfortunately no one can indicate those localities with any certainty before their discovery by actual experiment. The use of torpedoes for opening fissures and loosening up compact strata, has given excellent results in the oil wells of western Pennsylvania, and it is probable that they would be still more efficacious in promoting the flow of gas from the close and solid strata which underlie Cleveland. The experiment is at least worth trying.

OIL WELLS.

During the prevalence of the oil excitement which overspread the country ten years since, many wells were bored for petroleum in Cuyahoga County; one at Brighton, several in the valley of the Cuyahoga, one in the valley of Rocky River, one at Kingsbury's quarry and several fur-

ther eastward, in Mayfield, Warren and Euclid. The efforts in these latter localities were prompted by the petroleum which so frequently saturates the fine-grained sandstone which locally replaces the lower portion of the Bedford shale, and the oil springs which flow from the quarries and exposures of this rock. The oil of this horizon is clearly derived from the underlying bituminous mass of the Cleveland shale. But this deposit of carbonaceous matter is conparatively thin; and as it is freely drained, although a constant flow of oil takes place from it, no accumulation of this oil has occurred, and the wells bored to obtain it have failed to repay their cost. The wells in the valley of the Cuyahoga have reached down to the lower oil horizon—that of the Huron shale—and oil has been obtained, perhaps, in all of them, but from the compactness of the strata, and the absence of reservoirs to receive any flow from the oil rock, the quantity has been uniformly small. In all of these deep borings nothing but shale has been penetrated; the sandrocks which constitute the oil reservoirs in Pennsylvania having been replaced by fine argillaceous sediments. This, in itself, is perhaps a sufficient reason why the oil wells of this region have been failures. As the sandstones are everywhere more or less jointed, and hold in their texture, where saturated, a considerable quantity of oil, they constitute, even when undisturbed, better reservoirs than close, impervious clay shale. We are probably justified by the experience of the past, in predicting, that no considerable quantity of oil will at any time be obtained from wells bored in Cuyahoga County.

COAL.

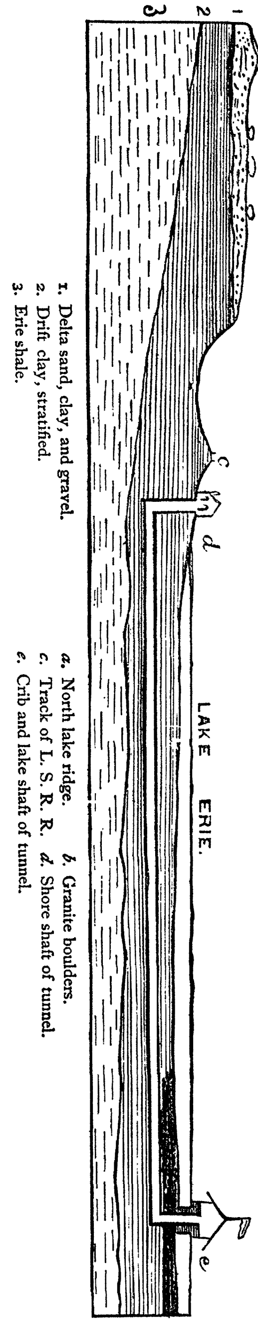
The black shale which forms part of the Waverly series sometimes contains thin sheets of coaly matter, which have excited false hopes of finding coal in numerous localities. On Rocky River considerable money has been expended in the search for coal in this formation. To prevent further disappointments of this kind, I take occasion to say here, again, that all the rocks of Cuyahoga county lie below the Coal Measures, and that every effort to find workable seams of coal within the county, must necessarily result in failure.

MINERAL SPRINGS.

Sulphur springs may be found in almost every township in the county. A large number of such have come under my observation, and the localities where they exist would form a long list. There are none, however, of which I have any knowledge, which by their copiousness or the composition of their waters seem to require notice.

THE LAKE TUNNEL.

The interest, both scientific and practical, which this public work has excited, seems to demand some reference to it in this report. The success of this and all similar enterprises, undertaken on the shores of the lakes, is greatly favored by, if not entirely dependent upon, that peculiar feature in the structure of the lake basins which has been referred to in the preceding pages, namely, their deep excavation by ice, and the subsequent accumulation upon their rocky bottoms of a considerable thickness of clay. Had the immediate bottom of Lake Erie at Cleveland been composed of rock, the excavation of such a tunnel as is now being made, would not only have involved an immensely increased expenditure of money and time, but it is even probable that the difficulties which must have then been encountered would have been so great as to be practically insurmountable. The object of this work, as is generally known, is to obtain for the City of Cleveland an abundant supply of pure water. This it is hoped to accomplish by running a tunnel under the bottom of the Lake so far from the shore as to draw through it water that shall be uncontaminated, either by the wash of the shore or by the drainage discharged at the mouth of the Cuyahoga. The general drift of the water in the Lake being toward Buffalo, the discharge from the river is deflected in that direction; as may be seen from the curve formed outside of the piers by the current of the river when it is rendered turbid and visible by freshets. The tunnel was therefore located on the west side of the river, and is about a mile from its mouth. There a shaft was sunk to the depth of 67 feet, and from its bottom a tunnel was driven almost horizontally toward the center of the Lake. A mile and a quarter from the shore a crib was planted and a shaft sunk



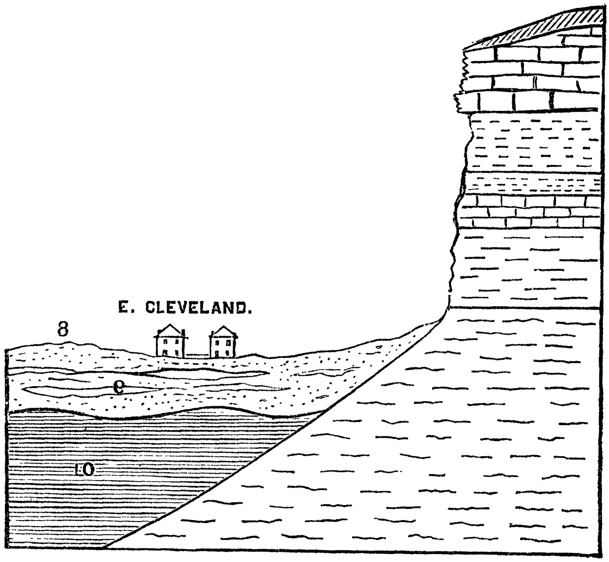
Profile Section of the Lake Tunnel, Cleveland.

to the depth of 65 feet below the surface of the water; and from this point a gallery was carried shoreward. The tunnel was arched with brick as it progressed, and is now more than half completed. The excavation has been made entirely in clay and would by this time have been finished but for the bursting in of water from below, by which the work has been seriously retarded. The general features of the tunnel will be seen at a glance by reference to the accompanying profile, which has been constructed from observation during its progress, and from facts given me by Mr. John Whitelaw, the engineer in charge.

From preliminary observations it was found that at the shore the bed of clay overlying the rock extended to a depth of 78 feet below the Lake level. At the crib the rock was found at the depth of 116 feet, the water being there 24 feet deep. The rock underlying the Drift clay is the Erie shale, such as forms the Lake shore both east and west of the Cuyahoga. The tunnel is located near the western margin of the old, deeply excavated Cuyahoga valley, and the clay would have been found thicker further east; thinner towards the west. In the profile the overlying delta deposit, mainly stratified sand and gravel, is shown. This caps the shore bluffs and underlies the city. One of the ridges which runs parallel with the Lake shore is also indicated in its relative position and altitude. The material taken from the tunnel has been nearly the same throughout, a fine blue clay thickly set with small angular fragments of the Erie and Huron shales; doubtless excavated from the Lake bottom by glacial action. There have also been found in the tunnel a few small boulders,—generally striated,—composed of granite, greenstone or crystalline limestone. The clay penetrated by the tunnel has seemed to be without stratification; but, as we learn from the boring made at the Standard Oil Works—of which a record is given on another page—the clays which fill the old Cuyahoga valley are bedded, though in a large way, and form strata of 25 to 30 feet in thickness, separated by sheets of sand and gravel. These sheets are water bearing, and there is little doubt that the accident which occurred in the tunnel was occasioned by the proximity of one of them.

The following sections will be of interest to the residents of different portions of the County:

Section of the Cliffs at East Cleveland.



1. Soil and drift clay, 10–30 feet.
2. Berea grit, 30 feet exposed.
3. Red shale, 38½ ft.
4. Blue shale, 15 feet.
5. Blue sandstone, 20 feet.

Bedford shale.

6. Cleveland shale, black, 55 feet.
7. Erie shale, 132 feet to lake level.

8. North lake ridge. 9. Delta sand and clay.
10. Drift clay in old valley of the Cuyahoga.

Section of Strata at Bedford.

No. 1.	Superficial materials, clay-loam, with numerous fragments of sandstone and some Eozoic boulders		10–30
" 2.	Gray argillaceous shale (Cuyahoga shale), exposed		30
" 3.	Thin-bedded, yellow sandstone with *Discina Newberryi* and *Lingula melia;* surface 350 feet above Lake Erie	Berea Grit.	10
" 4.	Gray shale	Berea Grit.	6–4
" 5.	Thick-bedded, yellow sandstone with ripple marks	Berea Grit.	45
" 6.	Blueshale (Bedford shale) with many fossils—*Syringothyris*, etc.—at base		71
" 7.	Black bituminous shale, (Cleveland shale) with fish teeth and scales....		21
" 8.	Hydraulic limestone with *Macrodon* and *Syringothyris*		4
" 9.	Green shale (Erie shale) with *Leiorhynchus mesacostalis, Spirifer disjunctus*, etc., exposed		60

Section of rocks in the valley of Rocky River, from Berea to Lake Erie.

		FEET.
No. 1.	Drift clay	6–12
" 2.	Cuyahoga shale with *Lingula, Discina*, etc	10
" 3.	Berea grit, upper bench shelly, lower massive	60
" 4.	Red shale with thin calcareous bands containing *Macrodon* and *Lingula*	15
" 5.	Gray shale, no fossils seen	60
" 6.	Black bituminous shale with fish scales (Cleveland shale); northern outcrop at second bridge above mouth of Rocky River	50
" 7.	Gray and green shales with thin bands of sandstone, no fossils seen, (Erie shale)	100
" 8.	Lake surface.	

The old, clay-filled valley of Rocky River is cut into by the new valley, at the second bridge from the Lake, in Rockport. There the east side of the gorge is composed of the Erie and Cleveland shales, the west side of clay. A cross-section of the old clay-filled valley may be seen on the Lake shore near the residence formerly occupied by Gov. Wood. The highest and lowest of the Lake ridges may be seen crossing the old valley of Rocky River on the surface of the series of Drift deposits with which it is filled; showing that the ridges are more modern than any part of that series.

Section on Euclid Creek.

1.	Soil and Drift clay.	
2.	Blue shale (Bedford shale).	
3.	Blue, fine-grained sandstone with oil and gas; quarried................	20 ft.
4.	Black, bituminous shale, (Cleveland shale) source of oil and gas.....	60 ft.
5.	Blue argillaceous shale, with thin flags of sandstone and layers of flattened nodules of iron ore (Erie shale) to creek....................	45 ft.

Section on Big Creek above Brighton.

1.	Soil and Drift clay; surface 210 ft. above Lake Erie....................	25 ft.
2.	Black bituminous shale (Cleveland shale)..................................	60 ft.
3.	Blue argillaceous shale (Erie shale) to creek at mouth.................	90 ft.

A well bored by Mr. Poe, 400 feet below the bottom of the ravine, is reported as all in Erie shale. At the mouth of the creek heavy beds of clay cut out the rock strata; the old valley of the Cuyahoga being reached here.

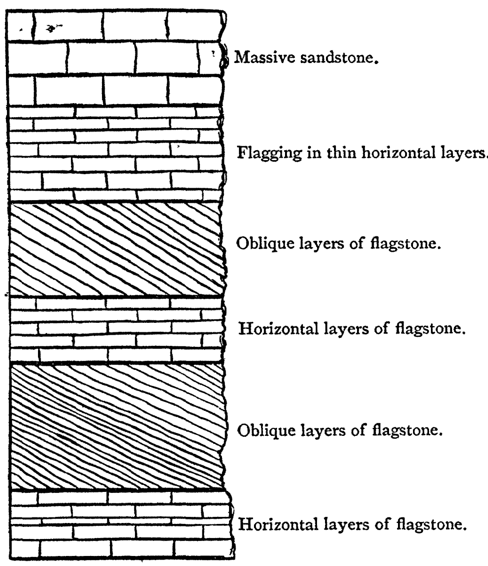
STRATA EXPOSED IN THE VALLEY OF CHAGRIN RIVER.

At Chagrin Falls, the Berea grit forms the upper and lower falls. It is generally less massive than at most other exposures. The upper portion affords very good flagging, and has been quarried for many years by Mr. Hanibal Goodale. The surfaces of the flags are generally ripple-marked, showing that they were deposited in shallow water; and many of them are pitted with marks of rain drops; indicating temporary exposure to the air. The Cuyahoga shale is here only about 100 feet thick; much thinner than at any other known locality. This diminution in thickness is probably due to the erosive action of the currents which deposited the Conglomerate. At the base of the Cuyahoga shale a thin stratum is crowded with *Lingulae* and *Discinae*, with scales of *Paleoniscus* and flattened, striated stems of fucoids. The quarries of Mr. Goodale have furnished a large number of specimens of *Paleoniscus Brainerdi*, which have been carefully preserved by the proprietor. This fossil, though so

abundant here, has never been found in any other locality. At the junction of the two branches of Chagrin river, 25 feet of the Berea grit are exposed, which show it to be more massive than at Chagrin Falls village. The Bedford shale is here well shown below the Berea, though the bottom of the formation is not seen. An oil well was sunk some years since, on the farm of Mr. Hoffman, to the depth of 282 feet, beginning at the base of the Berea and penetrating deeply into the Erie shale. Salt water was obtained from this well, a copious flow of gas and some oil, but not enough to warrant pumping.

Two miles north of Gates' Mill the banks of the river are high, and the Erie shale is exposed at their base. Near Gates' mills, about 200 feet above the stream, at Luther's quarry, the Berea sandstone is worked. It is here more massive than at Chagrin Falls, forming layers from 2 to 4 feet in thickness, and is a good building stone, though somewhat stained with iron. At a saw mill, one mile east of Gates' Mill, a deep gorge cuts through the Berea sandstone, exposing the shale below. The grit here affords beautiful examples of cross stratification, of which a representation is given in the cut below.

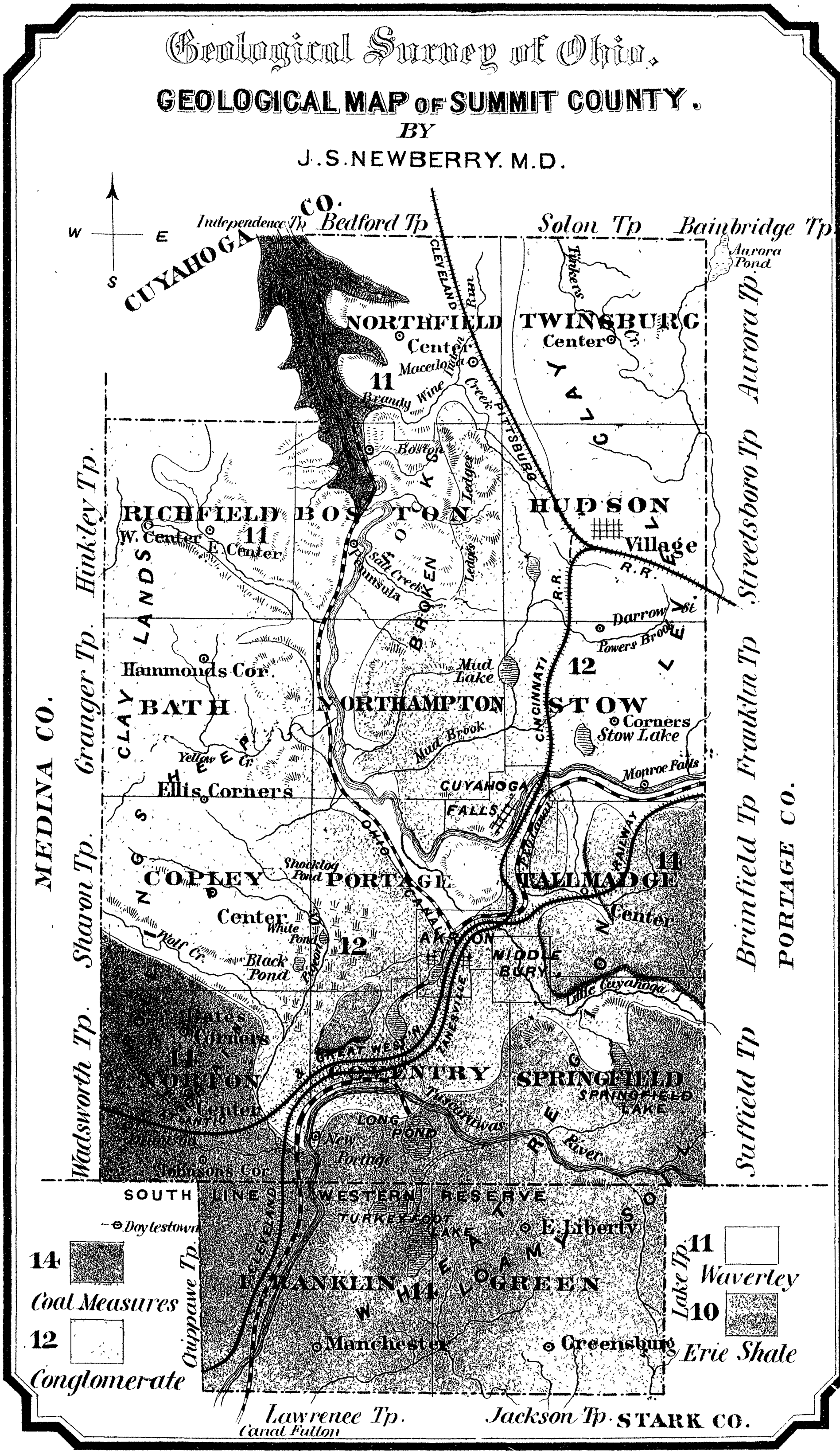
Oblique Stratification of Berea Grit.



This oblique stratification has been something of a puzzle to quarrymen and others, here and elsewhere. Its mode of formation* is, however, very easily explained. When sand is moved by broad and shallow currents of water—such as the ebb and flow of the tide produces — it is pushed along the bottom and fills depressions by the deposition of successive layers, at first having the angle of the margin of the pool or channel; the subsequently deposited layers becoming more nearly horizontal as the depression is filled up. Sand bars in streams are formed in the same way; as may be seen by any one who will take the trouble to observe the process. In "Bear's Gully," not far from Gates' Mill, is another exposure of Berea grit, where 42 feet of reddish brown shale (Bedford shale) are seen underlying it. In a ravine just below Macksville, the black, Cleveland shale,

is exposed; its surface about 70 feet below the Berea grit. The shale is here, apparently, but 23 feet in thickness. In "Fletcher's Gully," near Macksville, the Berea has a thickness of about 60 feet, the upper portion thin-bedded as usual, and the whole resting upon gray shale. A fine spring of water, holding a large amount of iron in solution, gushes from the rock at this point. This is a good example of the series of springs which mark the line of junction of the great sandstone beds of the county—the Conglomerate and Berea grit—with their underlying shales, the Cuyahoga and Bedford. The theory of these springs is very simple: Surface water reaching the porous and jointed sandstones, passes freely through them, but is arrested in its descent by the impervious clay rocks below. Hence it accumulates in the bottom of the sandstones, supplying wells which penetrate them, or, flowing off along the line of dip, forms springs at the junction of the strata in any ravine or valley by which they are cut.

From Macksville to Willoughby the Erie shale forms continuously the bed of Chagrin river, and for the most part the mass of the bluffs or cliffs which border it.



Strobridge & Co. Lith. Cin.

CHAPTER VII.

REPORT ON THE GEOLOGY OF SUMMIT COUNTY.

BY J. S. NEWBERRY.

SURFACE FEATURES AND DEPOSITS.

Summit County, like Portage and Medina, is situated on the highlands which separate the tributaries of the Ohio from the waters draining into Lake Erie. It has an average elevation of about five hundred feet above the Lake, and, except that it is deeply excavated, almost centrally, by the valley of the Cuyahoga, its topography would be without marked features. Owing to this cause, however, it presents much more variety of surface than most of the counties of the state. The Cuyahoga river, rising in the northern portion of Geauga County, runs for forty miles in a south westerly direction; then, in the center of Summit County, turns sharply to the north and pursues a nearly straight course to the Lake. In Geauga and Portage, the Cuyahoga flows on the surface of a plateau composed of the Carboniferous Conglomerate. At the town of Cuyahoga Falls, in Summit county, this plateau is cut through in a series of cascades which give rise to much beautiful scenery. The river here falls two hundred and twenty feet in two miles, so that from the vicinity of Akron to the north line of the county, it flows through a narrow valley or gorge more than three hundred feet deep. At frequent intervals the Cuyahoga receives tributaries from both the east and west, and the valleys of these streams contribute their part to give variety to the topography of the central portion of the county.

The highest lands in Summit county are the hills most distant from the channels of drainage, in Richfield, Norton, Green, Springfield, Tallmadge and Hudson. In all these townships summits rise to the height of six hundred and fifty feet above the Lake. The bottom of the Cuya-

hoga valley, in the northern part of Northfield, is less than fifty feet above Lake Erie, so that within the county we have differences of level which exceed six hundred feet.

Altitudes in Summit County.

	FEET ABOVE LAKE ERIE.
Tallmadge, Long Swamp,	470
" road east of center,	543
" Coal No. 1, Newberry's mine	520
" " " D. Upson's mine	492
" summit of Coal Hill	636
Akron, door-sill of Court House	452.65
" Rail Road Depot	428.13
" summit level, Ohio Canal, high water	395
" P. & O. Canal	370.64
Cuyahoga Falls, Railroad Depot	428.13
Monroe Falls, road before Hickok house	460
Hudson station	496
" town	547
Boston, Ohio Canal	94.66
Peninsula, "	125.66
Yellow Creek, "	180
Old Portage, "	188
Green, Summit of Valley R. R	532
New Portage, street in front of Tavern	400
Lake between New Portage and Johnson's Corners	399
Wolf Creek, below Clark's Mill	390.74
" in Copley, 1 mile west of north and south center road	419.78
Little Cuyahoga, Mogadore	477
" " at Gilchrist's Mill Dam	457
" " Old Forge at Trestle	439
Richfield, East Center	531.80
" highest land (over)	675
Yellow Creek, one-fourth mile west of Ghent	371

The soil of Summit county is somewhat varied. In the northern part, even where underlaid by the Conglomerate in full thickness, the soil derived from the Drift contains a great deal of clay, and Northfield, Twinsburg, Hudson, etc., are, as a consequence, dairy towns. The southern half of the county, however, has a loam soil, and the attention of the farmers has been directed more to grain growing than stock-raising. This difference of soil was clearly indicated by the original vegetable growth. In Hudson and Twinsburg the forest was composed, for the most part, of beech, maple, basswood and elm, while in Stow, Tallmadge, and southward the prevailing forest growth was oak. In Franklin and Green the soil is decidedly gravelly; the original timber was oak, in

groves and patches, and these townships form part of the famous wheat-growing district of Stark, Wayne, &c.

In the central part of the county, between Akron and Cuyahoga Falls, a few thousand acres, called *The Plains*, formerly presented a marked contrast to the rolling and densely timbered surface of all the surrounding area. This is a nearly level district, of which the peculiar features are mostly obliterated by cultivation, but when in the state of nature it had the aspect of the prairies of the West. It was almost destitute of timber, was covered with grass and scrub oak (*Quercus Banisteri*) and in spring was a perfect flower garden; for a much larger number of wild flowers were found here than in any other part of the county. The origin of these peculiar features may be traced to the nature of the substructure of the district. This area forms a triangle between the two branches of the Cuyahoga and the coal hills of Tallmadge; the soil is sandy, and this is underlaid by beds of gravel of unknown depth. It seems that there once existed here a deeply excavated rock basin, which was subsequently partly filled with drift deposits and partly by water; in other words, that it was for a time a lake. The waters of this lake deposited the sand which now forms the soil, and in its deeper portions a series of lacustrine clays, which are well shown in the cutting recently made for a road on the north side of the valley of the Little Cuyahoga near Akron. The section of these beds is as follows:

		FEET.	IN.
1.	Stratified sand	10	..
2.	Blue clay	...	4
3.	Mixed Yellow sand and Blue clay, stratified	1	1
4.	Blue clay	...	10
5.	Yellow clay	...	10
6.	Blue clay	1	...
7.	Red clay	...	1
8.	Yellow clay	1	...
9.	Blue clay	...	8
10.	Red clay	...	2
11.	Blue clay	...	6
12.	Red clay	...	10
13.	Blue clay	1	6
14.	Red clay	...	2
15.	Yellow clay	1	6
16.	Blue clay	2	...
17.	Red clay	...	1
18.	Fine Yellow sand	...	1
19.	Yellow clay	2	...
20.	Blue clay	...	4
21.	Yellow clay	3	...
22.	Blue clay	4	...

In another section, exposed near by in the valley of the Little Cuyahoga, the beds which have been enumerated are seen to be underlaid by about 60 feet of stratified sand and gravel, to the bed of the stream. To what depth they extend is not known.

On the opposite side of the Little Cuyahoga, on the main road leading into Akron, the banks of the old valley present a very different section from either of those to which I have referred above. There we find a hill composed of finely washed and irregularly stratified sand, quite free from pebbles. About ten or twelve feet of the upper part is yellow; the lower part, as far as exposed, white; a waved line separating the two colors.

East and north of the locality where the detailed section given above was taken, heavy beds of gravel are seen to occupy the same horizon; from which we learn that these finely laminated clays were deposited in a basin of water, of which the shore was formed by gravel hills.

A portion of the city of Akron is underlaid by thick beds of stratified sand and gravel. These are often cross-stratified and show abundant evidences of current action. They also contain large angular blocks of Conglomerate and many fragments of coal; some of which are of considerable size. We apparently have here some of the materials which were cut out of the valleys that separate the isolated outliers of the Coal Measures which are found in this part of the county.

Beds of gravel and sand stretch away southward from Akron, and form part of a belt, which extends through Stark County, partially filling the old, deeply-cut valley of the Tuscarawas, and apparently marking the line of the southern extension of the valley of the Cuyahoga, when it was a channel of drainage from the Lake basin to the Ohio. This old, and partially obliterated channel, has been referred to in the chapter on the Physical Geography of the state, and it will be more fully described in the chapters on Surface Geology, and those formed by the reports on Stark and Tuscarawas counties. I will only here refer to it in passing to say, that the line of the Ohio canal—of which the summit is at Akron—was carried through this old water gap, because it still forms a comparatively low pass. In the western part of the state, the Miami canal traverses a similar pass; and another, having nearly the same level with those mentioned, in Trumbull County, connects the valleys of Grand river and the Mahoning.

The thick beds of gravel and sand which underlie the plain and stretch eastward up the valley of the Little Cuyahoga through southern Tallmadge, perhaps form part of the great gravel belt to which I have already alluded, but may be of more local origin. It seems to me quite

possible that in former times the Cuyahoga passed eastward of its present course, from Kent or Monroe Falls to Akron; that the falls of the Cuyahoga were then near the "Old Forge," and that this excavated basin beneath the "Plains" was scooped out by them. We know that the position of the falls has been constantly changing; that they were once in Cuyahoga County, and have gradually receded to their present position. When they had worked back to the great bend of the Cuyahoga, they seem to have swung round the circle for some time before starting on their present line of progress. In this interval the river appears to have flowed over a broad front of the Conglomerate, and, cutting away the shales below, to have produced the rock basin which has been described.

When the falls of the Cuyahoga were at the north line of the county, they must have had a perpendicular height of at least 200 feet, for the hard layers in the Cuyahoga shale which produce the "Big Falls" do not extend so far north. The entire mass of the Cuyahoga shale there is soft argillaceous material, which must have been cut out beneath the massive Conglomerate, producing a cascade at least equal in height to that of Niagara.

The north-south portion of the Cuyahoga valley seems to have been once continued southward, and to have been connected with the old valley of the Tuscarawas, which is excavated far below the bed of the present stream. At the north line of the county, the valley of the Cuyahoga is cut down 220 feet below the present river bottom; as we learn by wells bored for oil. The bottom of the valley of the Tuscarawas is, at Canal Dover, 175 feet below the surface of the stream, and there are many facts which indicate that there was once a powerful current of water passing from the Lake basin to the Ohio through this deeply excavated channel. Subsequently this outlet was dammed up by heavy beds of Drift, and the Cuyahoga, cut off from its connection with the Tuscarawas, to which it had been a tributary, was forced to turn sharply to the north, forming the abrupt curve that has been always regarded as a peculiar feature in the course of this stream. The courses of the tributaries of the Maumee are not unlike that of the Cuyahoga, and are probably dependent upon the same cause, namely, the depression of the Lake level, and the diversion of the drainage from the Mississippi system—with which it was formerly connected—into the Lake basin.

The Drift clays, which underlie the northern part of Summit County, are plainly of northern origin, as they contain innumerable fragments of the Huron, Erie and Cuyahoga shales, and no such mass of argillaceous material could be derived from the Conglomerate and Coal Measures which underlie all the country toward the south.

The direction of the glacial striæ in the county is nearly north-west and south-east, and these clays are plainly the result of glacial action. It is interesting to note, however, that in the Drift clay at Hudson a large number of masses of coal have been found, some of which were several inches in diameter. This fact, taken in connection with the character and history of the Drift clays, proves—what we had good reason to believe from other causes—that the coal rocks once extended at least as far north as the northern limits of the county, and that from all the northern townships they were removed and the Conglomerate laid bare by glacial erosion.

A considerable portion of the Drift gravels in the southern part of the county are of foreign and northern origin. As I have elsewhere remarked, these gravels and the associated lands show distinct marks of water action, and have apparently been sorted and stratified by the shore waves of the Lake when it stood several hundred feet higher than now.

The boulders which are strewn over the surface in all parts of the county are mostly composed of Laurentian granite from Canada, and I have attributed their transportation to icebergs. In Northampton many huge boulders of Corniferous limestone are found, and these evidently came from the islands in Lake Erie.

Lakes. One of the most striking of the surface features of Summit County is the great number of small lakes which are found there. These are generally beautiful sheets of pure water enclosed in basins of Drift gravel and sand. They form part of the great series of lake basins which mark the line of the water shed from Pennsylvania to Michigan, and they have been described, and their origin explained in the chapter on Physical Geography. When a resident of Summit County, I mapped and visited nearly one hundred of these little lakes within a circle of twenty miles radius drawn around Cuyahoga Falls.

Aside from the variety and beauty which these lakelets give to the surface, they afford many objects of scientific interest. They are usually stocked with excellent fish, and many rare and peculiar plants grow in and about them. They also contain great numbers of shells, some of which are rare. Springfield Lake, for example, is the only known locality of *Melania gracilis*, and Congress Lake contains two species of *Linnea*, (*L. gracilis* and *L. stagnalis*,) both of which are found in few if any other localities in the state.

Peat Bogs. Many of the lakes to which I have referred, are being gradually filled up by a growth of vegetation that ultimately forms peat. In all those lakes where the shores are marshy and shake under the tread, peat is accumulating. We have evidence, too, that many lakelets have

been filled up and obliterated by this process; for we find a large number of marshes in which there is now little water, but the surface is underlaid by peat and shell marl, sometimes to the depth of twenty or thirty feet. Every township contains more or less of these, and some of them are quite extensive. The larger ones are usually known as whortleberry swamps or cranberry marshes, sometimes as tamarack swamps, from the growth of larch which frequently covers the surface. Among the largest of these is that west of Hudson on Mud Brook, in which the peat is fifteen feet deep. Another lies east of Hudson, near the county line. In Stow, on Mud Brook, is a long peat swamp in which the depth of the peat is not less than thirty feet. In Coventry is one in which the peat is said to be thirty or forty feet deep, and from this considerable peat of excellent quality has been manufactured by Mr. J. F. Brunot. These peat bogs have excited some interest as possible sources of supply of fuel, and yet where coal is as cheap and good as in Summit County, it seems hardly probable that peat can be profitably employed as a fuel. The best of peat, when air dried, contains nearly 20 per cent. of water and 20 per cent. of oxygen, and has a heating power not greater than half that of our coals, while it occupies double the space. Hence, unless it can be produced at half the price of coal in the markets of Summit County, it can hardly compete with it. Peat is, however, an excellent fertilizer, and many, even of the smaller peat bogs, may be made very valuable to the agriculturist. In some localities such deposits of peat have been cleared up and cultivated for many years, without a suspicion that there was anything of interest or value below the surface.

Shell Marl. Deposits of Shell Marl are frequently found underlying peat in "cat swamps" and filled up lakelets. This marl is composed of the remains of the shells of mollusks, which after the death of the animals that inhabited them, have accumulated at the bottom of the water. In some instances these marls are white, and nearly pure lime; in others they are mixed with more or less earthy and vegetable matter. Such deposits occur in nearly every township of the county, but they have attracted little attention, and their valuable fertilizing property have been very sparingly made available. The deposit of shell marl on the road between Hudson and Stow on land of Charles Darrow is at least twelve feet deep and very pure. Similar marl-beds, though less extensive, are known in Hudson, Northampton and other parts of the county. Usually a sheet of peat or muck covers the marl, and it is not likely to be discovered, unless by ditching or special search. The simplest method of exploring marshes for peat or shell marl is with an auger made from an old two-inch or three-inch carpenter's auger welded to a small, square rod of

iron, on which a handle is made to slide, and fasten with a key. With this all marshes may be probed to the depth of eight or ten feet with the greatest facility.

GEOLOGICAL STRUCTURE.

Erie Shale. This is the lowest formation exposed in Summit County, and is visible only in the bottom of the valley of the Cuyahoga, where it is cut deepest, in the township of Northfield. About 100 feet of the upper portion of the Erie shale is exposed in the cliffs which border the river, being a continuation of the outcrops which have been fully described in the report on the geology of Cuyahoga County. The same fossils have been found in the Erie shale in Northfield, as those collected in the valleys of Chippeway and Tinker's Creeks.

WAVERLY GROUP.

The Lower Carboniferous or Waverly group is freely opened in the valley of the Cuyahoga, and we here find some of the most satisfactory sections of this formation that can be seen in the state. It has also yielded, perhaps, as large a number of fossils in Summit County as has been obtained from this group in any other localities. These will be more particularly noticed in connection with the strata that contain them.

Cleveland Shale. This is the bituminous shale which forms the base of the Waverly group, and has been fully described in the reports on the counties which form the northern border of the state. The outcrops of the Cleveland shale which are visible in the valley of the Cuyahoga, are continuations southward of those noticed in Cuyahoga County. As the dip of all the strata is here gently southward, and the valley gradually deepens towards its mouth, the Cleveland shale, though on the north line of the county more than 100 feet above the bed of the stream, sinks out of sight near Peninsula, less than ten miles from the county line. The average thickness of the Cleveland Shale in Summit county is about 50 feet, and it presents precisely the same lithological characters here as further north. No fossils have been discovered in it at the localities where it has been examined in this county, but more careful search would undoubtedly result in the discovery of the scales and teeth of fishes similar to those found at Bedford.

As in Trumbull, Cuyahoga and Medina counties, the outcrops of the Cleveland shale in Summit are marked by oil and gas springs, which

are plainly produced by the decomposition or spontaneous distillation of the large amounts of carbonaceous matter it contains. The oil and gas springs which have been noticed on the sides of the Cuyahoga valley at and below Peninsula are distinctly connected with the Cleveland Shale, and have, as a consequence, misled those who have been influenced by them to bore for oil in the bottom of the valley.

Bedford Shale. This member of the Waverly group is not well exposed in the valley of the Cuyahoga, though visible at a number of localities. Its out-crops usually form slopes covered with *debris* where the limits of the formation are concealed. Judging from the glimpses obtained of it, the Bedford shale is apparently about 70 feet thick in the valley of the Cuyahoga, and consists mainly of soft, blue, argillaceous strata, similar to those in the gorge of Tinker's Creek at Bedford. In some localities it is more or less red, and has been here, as elsewhere, used as a mineral paint. In the valley of Brandywine Creek, below the Falls, the Bedford shale is very fossiliferous, and contains the same species found at Bedford. Among these *Syringothyris typa* is the most conspicuous and abundant, and slabs may be obtained here which are thickly set with this fine fossil, forming beautiful specimens for the cabinet.

Berea Grit. The Berea sandstone is well exposed in the valley of the Cuyahoga in the northern part of the county, and forms two lines of outcrop—one on each side of the river—running from Peninsula to Independence on the west, and to Bedford and Newburg on the east. At Peninsula the Berea grit has been extensively quarried for many years. The base of the formation is here from 30 to 60 feet above the canal, so that the quarries are worked with facility, and their product shipped with comparatively little expense. The entire thickness of the formation in the valley of the Cuyahoga is about 60 feet. The stone it furnishes varies considerably in character in the different localities where it is exposed. At the quarries of Mr. Woods, at Peninsula, it is lighter in color than at Independence; resembling the Berea stone in this respect, as also in hardness. Some layers are nearly white, and a large amount of excellent building stone has been shipped from this locality and used for the construction of various public buildings at Cleveland, Detroit, Buffalo, Oswego, etc. This stone is more firm and durable, but is harder and less homogeneous than that from the Amherst quarries; it is, however, so highly esteemed that a ready market has been found for all that has been taken from the quarries. During 1871 the stone shipped from Peninsula was equal to 2800 car loads of ten tons each.

Between Peninsula and the county line the outcrops of the Berea grit have been but imperfectly explored. They are much obscured by the

debris of the higher portions of the cliffs, and the examinations necessary to determine the value of the stone would require the expenditure of considerable time and money. There is every probability, however, that good quarries could be opened at a great number of localities, and I think I am quite safe in predicting that in future years this portion of the valley of the Cuyahoga will be the theatre of a very active industry growing out of the quarrying of Berea grit for the Cleveland market. Should the railroad, now proposed, be constructed through the valley, this, with the canal, will supply such facilities for transportation that, if the quality of the stone should be found suitable, this district will contribute as largely as any other to the market of the great lakes. From the differences which are everywhere exhibited in the quality of the stone in neighboring outcrops of the Berea grit, the banks of the Cuyahoga should be carefully examined in order to discover such localities as will furnish stone of superior quality. It is not too much to expect that some of these will have great pecuniary value.

The Berea grit forms the solid stratum that produces the falls of the Brandywine, at Brandywine Mills, and it is here considerably more massive than at the outcrops further north on the same side of the Cuyahoga.

No fossils have been found in the Berea grit in Summit County. It is elsewhere, as a general rule, remarkably barren, and yet at Chagrin Falls fossil fishes have been obtained from it; and at Bedford a *Discina*, a *Lingula*, and an *Annularia*. These, and perhaps other fossils may hereafter be met with in the Cuyahoga Valley.

Cuyahoga Shale. This, the upper division of the Waverly group, is better exhibited in Summit County than in any other part of the state. It has a thickness of from 150 to 200 feet, and has been given the name it bears because it forms the greater part of the banks of the Cuyahoga from Cuyahoga Falls to the north line of the county. A short distance above Peninsula the Berea grit sinks beneath the river, and the whole thickness of the Cuyahoga shale is revealed in the interval between that rock and the Conglomerate which caps the bluffs. In this part of the valley the Cuyahoga shale exhibits little variety in composition, and consists of a mass of soft argillaceous material interstratified with thin and local sheets of fine grained sand-stone, rarely thick enough to serve as flagging. The surfaces of these sheets are marked with mud furrows, and occasionally with the impressions of fucoids. At the "Big Falls" of the Cuyahoga, 80 feet below the Conglomerate, a number of layers of fine-grained sandstone, from 6 to 12 inches in thickness, and occupying a vertical space of about 20 feet, locally replace the softer material of

the Cuyahoga shale and produce the beautiful waterfall at this locality. These harder strata may be traced for a mile or more down the river, but are not distinguishable in the sections of the Cuyahoga shale in the northern part of the county. The sandstone of the Big Falls is a compact homogeneous rock almost identical in character and utility with the "blue stone" of the East Cleveland quarries, although lying at a considerably higher level; the East Cleveland stone being a local modification of the lower portion of the Bedford shale. The upper part of the Cuyahoga shale near the Big Falls has furnished a great number of fine specimens of "cone-in-cone," and they are referred to by Dr. Hildreth in his notes on the Cuyahoga valley, published in Silliman's Journal in 1836. This singular structure has given rise to much speculation; it was at one time supposed to be organic; subsequently, the result of impeded crystallization; and it is now considered by Prof. O. C. Marsh as of purely mechanical origin. The "cone-in-cone" consist, as is well known, of a series of hollow cones, like extinguishers, placed one within another; and it sometimes makes up the entire mass of a stratum, several inches in thickness and many feet it lateral extent. It is by no means confined to this horizon, but is found in the older paleozoic rocks, in the Coal Measures, and is perhaps more abundant than anywhere else in the Cretaceous formation in the far West. This structure is apparently confined to rocks of a peculiar chemical composition, viz; to earthy limestones, or argillaceous shales impregnated with lime. The concretions, which include the great fishes of the Huron shale not unfrequently exhibit the cone-in-cone structure; and in some instances where the calcareous material forms simply a crust on the fossil, that crust still shows more or less of it. From the locality under consideration in the valley of the Cuyahoga, I have obtained specimens of "cone-in-cone" enveloping nodules of iron ore, and radiating in all directions from such nuclei. Specimens of this character, and the bones of *Dinichthys* coated in all their irregularities with "cone-in-cone," seem to me incompatible with the theory that this structure is the product of mechanical forces, and appear rather to confirm the conclusion that it is an imperfect crystallization.

Throughout most of its mass, and in most places, the Cuyahoga shale is very barren of fossils. This, however, is fully compensated for by the extreme richness of some layers and some localities. This is the rock which was excavated in the formation of the canal in the valley of the Cuyahoga below the falls, and through which an effort was made to conduct the water of the river to the proposed town of Summit. In this excavation the formation was fully opened for several miles, and yet with the most careful search, at various times during the progress of the work,

I was only able to obtain a mere handful of fossils. At the base of the formation, however, immediately over the Berea grit, the Cuyahoga shale is sometimes crowded with millions of *Lingula melia* and *Discina Newberryi.* The same species also occur at the Big Falls of the Cuyahoga and in the valley of the Little Cuyahoga, near Akron.

In the upper part of the Cuyahoga shale in various parts of Medina County, and at Richfield, in Summit County, immense numbers of fossils are found, and those which form a long list of species. These will be more fully described in the paleontological portion of the report. The Richfield locality is already quite famous, as extensive collections were made there before the commencement of the present survey by Messrs. Meek and Worthen and Dr. Kellogg. Quite a large number of crinoids were discovered here by the latter gentleman, which proved new to science, and were described by Prof. Jas. Hall.

Conglomerate. The Carboniferous Conglomerate underlies all the higher portions of the county, and forms the surface rock over all the middle and northern portions, except where cut through by the Cuyahoga and its tributaries. Though generally covered and concealed by beds of Drift, the Conglomerate is exposed and quarried in all of the townships north of Akron. It is, however, best seen in the valley of the Cuyahoga, where it forms cliffs sometimes 100 feet in perpendicular height. The rock is about 100 feet in thickness; generally a coarse-grained, light drab sandstone, but in some localities, and especially near the base of the formation, becoming a mass of quartz pebbles, with just enough cement to hold them together.

There are also some local bands of the Conglomerate which are red or brown in color, and furnish a building stone of great beauty. At Cuyahoga Falls such a band has been quarried for many years, and has been used for the construction of the best buildings in the town. This stone is brown, contains much iron, and is very strong and durable. At Akron a similar local stratum, in the Conglomerate at Wolf's quarry, has a deep, reddish-purple color, and forms, perhaps, the most beautiful building stone in the state. This has been quite extensively used in Cleveland, and it may be seen to good advantage in the beautiful residence of Mr. Randall Wade. Unfortunately, the quantity of this variety of building stone is apparently not large. Its peculiar color is probably due to the fact that the iron, of which it contains a large quantity, is in the condition of anhydrous sesquioxide, and has associated with it a small percentage of manganese.

Splendid sections of the Conglomerate are seen in the gorge of the Cuyahoga, below Cuyahoga Falls. Here nearly the entire thickness of

the formation is exposed, and vertical and over-hanging walls of 100 feet in height give great variety and beauty to the scenery. In descending the valley of the Cuyahoga the walls of Conglomerate recede from the river, of which the immediate banks are formed by the underlying shales. By the washing out of these, the blocks of Conglomerate have been undermined and thrown down; and thus the valley has been widened, until in Boston and Northfield the Conglomerate cliffs are several miles apart. They still preserve their typical character, however, and this is well exemplified by the "Ledges" in Boston, which—like those of Nelson, in Portage County, on the other side of the Conglomerate plateau—are favorite places of resort to the lovers of the picturesque.

The fossils of the Conglomerate are exclusively plants. These are generally broken and floated fragments, but are exceedingly numerous; their casts often making up a large part of the rock. In certain localities we find evidence that they have been gathered by the waves into some receptacle, and heaped up in a confused mass, like drift-wood on a shore at the present day. Since the Conglomerate is composed of coarse materials which could only be transported by water in rapid motion, it is evident all delicate plants would be destroyed from the trituration they would suffer in the circumstances of its deposition; hence, we only find here the remains of woody plants, and of these, usually only fragments. The most common plants are trunks and branches of *Lepidodendron*, *Sigillaria* and *Calamites;* also the nuts which have been described under the name of *Trigonocarpon*. Of all these, the *Calamites* are the most common, and they are sometimes entire; showing not only the upper extremity, but also the roots. More frequently, however, they are broken, and it is not at all uncommon to find the nuts to which I have referred, in the interior of a Calamite; indicating that when floated about they were washed into the hollow, rush-like stem. Generally, the plants of the Conglomerate are represented simply by casts; their carbonaceous matter having been entirely removed. Occasionally, however, a sheet of coal is found surrounding the cast of each, and in some localities every plant is preserved in this way; the amount of coal enveloping the casts corresponding to the quantity of woody matter in the plant. Still more rarely, where many plants have accumulated, their carbon has made an irregular coal seam; but never exceeding a few inches in thickness and a few rods or feet in extent. These coal seams, however, differ in many respects from coals of the overlying Coal Measure, as they have no underclays, are very limited in extent, and evidently represent heterogenous collections of drifted woody matter.

The pebbles of the more pebbly portions of the Conglomerate are sometimes as large as one's fist, but more generally range from the size of a

hickory nut to that of an egg. They are almost always composed of quartz, but in every locality where they are abundant, more or less of them may be found which are composed of quartzite or silicious slate, which shows lines of stratification. Sometimes these quartz pebbles, when in contact with the impressions of plants, are distinctly marked by such impressions. This circumstance has given rise to the theory that they are concretionary in character; i. e. that they have been formed where found, and are not fragments of transported quartz rock. There can be no question, however, that these pebbles are portions of quartz veins, which have been brought hundreds of miles from some area where metamorphic, crystalline rocks have suffered erosion. In the process of transportation the attrition to which these fragments were subjected comminuted all but the most resistant, viz: the quartz. The banded, silicious slates which are represented in the pebbles that accompany those of pure quartz, as well as the internal structure of the quartz pebbles themselves, afford conclusive evidence that their origin is such as I have described.

The transmission of the surface markings of *Lepidodendron* and *Sigillaria* to quartz pebbles, is a surprising fact, and yet, as I think, not an incomprehensible one. These markings are very obscure, and are, indeed, little more than the flattening of the sides of the pebbles which were in contact with the plant stems. My explanation of this flattening is that some portion of the substance of the pebbles has been removed by solution, and it is quite possible that the potash originally contained in the plants has contributed something to this result by the formation of a soluble silicate.

The distribution of the materials composing the Conglomerate will be fully discussed in another portion of the report; I will, however, say here in passing, that I have for many years been inclined to refer the transportation and deposition of the immense beds of quartz pebbles which are found in the Conglomerate to the same cause which has transported the gravels of the Drift, and the similar deposits which are now accumulating on the sea bottom off the Antarctic Continent, and on the Banks of New Foundland—viz: to ice.

Coal Measures.—All the southern part of Summit County is underlaid by the productive Coal Measures, and workable seams of coal are known to exist in Tallmadge, Springfield, Coventry, Norton, Copley, Franklin, and Green townships. The line of the margin of the coal basin passes from Portage County into Summit in the north-eastern portion of Tallmadge. It thence runs westerly nearly to Cuyahoga Falls, and there sweeps round to enclose what is known as *Coal Hill;* the continuity of

the Coal Measures being severed by "Long Swamp" and the valley of Camp Brook. On the east side of this stream the outcrop of the coal rocks passes southward to the valley of the Little Cuyahoga; turning up this to the line of Portage County; thence, sweeping back on the south side of the valley across the township of Springfield to the vicinity of Middlebury. It thence runs south-westerly to New Portage, where it crosses the Tuscarawas, and strikes north-westerly through Norton and the corner of Copley to the Medina line. There is also a narrow patch of Coal-Measure-rocks forming an isolated hill ("Sherbondy Hill") south-west of Akron, on the west side of Summit Lake. Along the line I have traced we find the outcrops of only the lowest coal seam,—Coal No. 1; the "Briar Hill" coal—and this not with any great constancy, inasmuch as the coal occupies limited basins, and their margins are exceedingly sinuous and irregular. A large part of the territory which holds the place of the coal fails to hold the coal itself, from one or the other of two causes, which frequently disappoint the miner in this region, as well as in the valley the of Mahoning. These causes are; first, that the lowest seam of coal was formed from peat-like carbonaceous matter which accumulated on the irregular bottom of the old coal marsh, and the margin of this marsh ran into innumerable bights and channels which were separated by ridges and hummocks where the coal was never deposited; second, in many localities where the coal was once formed it was subsequently removed by erosion. The heavy bed of sandstone which lies a little above Coal No. 1 was deposited by currents of water moving rapidly and with such force as to cut away the coal in many channels, and leave in its place beds of sand, which, subsequently hardened, have become sandstone. These are frequently encountered by the miner, and are designated by him, as *horsebacks*. Hence, this excellent stratum of coal has been discovered to be wanting over much of the area where it was supposed to exist, and has therefore been of less value to Summit County than was anticipated in the earlier days of coal mining. The first mineral coal used on the Lake shore was sent to Cleveland by my father, Henry Newberry, from his mines in Tallmadge in 1828. It was then offered as a substitute for wood in the generation of steam on the Lake boats. Wood was, however, so abundant and the population was so habituated to its use, that it proved very difficult to supplant this by any other fuel; and it was necessary that nearly twenty years should pass before the value of the coal beds of Summit County was fully realized. Then coal mining began with considerable vigor, and many thousand tons of excellent coal have since been sent every year to Cleveland from the mines in Tallmadge and Springfield. As has been stated, the coal

of these townships proved to be very irregular in its distribution, and variable in thickness and quality. It is restricted to basins of limited extent, and is wanting over much of the area where it was supposed to be present. In the deeper portions of the basins or channels it occupies, the seam is from 4½ to 6 feet in thickness, and the coal a bright, handsome, open-burning variety, containing little sulphur and a small percentage of ash. It is softer and more bituminous than the coal of the same seam in Mahoning and Trumbull counties, but is still capable of being used in the raw state in the furnace, and is very highly valued both as a steam coal and household fuel. In the southern part of the county Coal No. 1 is more continuous, and has been proved by recent researches to exist over a large part of Springfield, Franklin and Green, and to reach into Coventry and Norton. Many mines have been opened in the townships referred to, and about 250,000 tons are now sent from this region annually to Cleveland. Most of this coal is similar in quality to that of Tallmadge, but in some localities, as at Johnson's shaft in Franklin, we find a recurrence of the block character which distinguishes the coal of Mahoning valley. In former years nearly all of the coal used or exported from the county was mined in Tallmadge, and this mainly from "Coal Hill," which lies between the center of Tallmadge and Cuyahoga Falls. Several mines were once in active operation in this hill. Of these mines, that of Henry Newberry was situated at the north end of the hill, and those of Dr. D. Upson, Asaph Whittlesey and Francis Wright on the east side. On the opposite side of the valley, mines were opened by Mr. D. Harris and Dr. Amos Wright. In all these mines the coal has been nearly exhausted, as it was found to rise and run out in the interior of the hill. From this fact a belief has come to be quite general that the coal is pinched out in the body of this and other hills by the weight of the superincumbent material; whereos we have here only an instance of what has been before referred to, of the thinning out of the coal on the margin of the old coal swamp. In the central and eastern portion of Tallmadge most of the land rises high above the coal-level, and basins of coal will doubtless be hereafter discovered there, but the same causes which have rendered coal mining so uncertain heretofore, will undoubtedly limit the productiveness of the nominally large coal area which is included within the township lines. In the southern part of Tallmadge the surface is occupied by heavy beds of Drift by which the underlying geology is very much obscured. Here, as in the adjoining township of Brimfield, in Portage County, nothing but patient and careful search will determine the limits of the basins of coal which unquestionably exist in this vicinity. As the dip of the coal rocks is towards the south and east, in Springfield, Green and Franklin, Coal No. 1 lies lower than in the

more northerly townships where it occurs; hence it can only be reached by boring, and that sometimes to the depth of 100 or perhaps even 200 feet. We have every reason to believe, however, that a considerable area in Green township is underlaid by Coal No. 1, where it lies far below drainage; and it is almost certain that careful search by boring will reveal the presence of basins of coal in this township, such as are not now suspected to exist, and such as will contribute largely to the wealth of the county.

In Summit County the lowest seam of coal is usually separated from the Conglomerate by an interval of from 25 to 50 feet, which is filled with shale or shaly sandstone, and, immediately beneath the coal, by a seam of fire-clay from 2 to 6 feet in thickness. This fire-clay is in some places of good quality, and may be used for fire-brick and pottery, but it is generally more sandy and contains more iron than the under clay of the higher seam—Coal No. 3—to which I shall have occasion to refer again. Coal No. 1 is usually overlaid immediately by grey shale, from 10 to 40 feet in thickness. This shale contains, especially where it forms the roof of the coal, large numbers of fossil plants, which are frequently preserved in great beauty and profusion. About 150 species have already been collected from the shale of Coal No. 1, in the northern part of the state, and nearly all of these are found in Summit County. More detailed descriptions of these plants will be found in another part of our report.

Coal No. 2. Thirty to fifty feet above Coal No. 1, we find, in many parts of Summit County—as in the valley of the Mahoning—the second seam of Coal in the ascending series, which we have called Coal No. 2. It is usually from 12 to 18 inches in thickness, and though persistent over a large area, is nowhere in Summit County of workable thickness.

Above Coal No. 2, and frequently cutting it out, is a bed of massive sandstone, which is a marked feature in the geology of the county. This is well seen in Coal Hill, Tallmadge, and extends through the southern part of the county, passing into Stark, where, in the valley of the Tuscarawas, about and above Massilon, it is quarried in many places along the bank of the canal. The thickness of this sandstone varies very much in different localities, and it may be said to range from 40 to 100 feet. It is also somewhat variable in character, but is often massive, and affords a building stone of excellent quality. It may generally be distinguished from the sandstones of the Carboniferous Conglomerate by the absence of quartz pebbles. So far as I know, no pebbles are found in the sandstone over the coal in Summit County. In Trumbull and Medina there are some local exceptions to this rule, for patches of Conglomerate sometimes found there immediately overlying the lowest

coal seam. These will be described elsewhere, and I merely refer to them here to indicate their exceptional character. In Summit County the "pebble rock," found in the explorations for coal, affords infallible evidence, when it is reached, that the horizon of the coal has been passed.

Coals No. 3 *and* 4. Near Mogadore, in Springfield township, the higher lands are found to be underlaid by a stratum of limestone, beneath which are usually a thin seam of coal and a thick stratum of fire-clay; the latter supplying the material from which nearly all the stoneware of the county is manufactured. From 25 to 40 feet above the limestone to which I have referred is another which also overlies a coal seam. Both these may be seen in Green township, between Greenburg and Greentown; and they may be traced thence, southerly, through Stark, Tuscarawas and Holmes counties, and indeed nearly or quite to the Ohio river. These are the "limestone coals" that will be found frequently referred to in the reports on the counties that have been mentioned, and those on Portage, Trumbull and Mahoning. The lowest of these limestones lies from 130 to 160 feet above Coal No. 1; the upper limestone about 150 to 200 feet. Hence they will serve as useful guides in boring for the lower coal seam in those parts of the county where it lies considerably beneath the surface.

ECONOMIC GEOLOGY.

In my notes on the different geological formations represented in Summit county, I have incidentally memtioned most of the important elements in its mineral resources. A few additional facts, however, require to be reported, to give a fair exposition of the subject.

Coal No. 1. I have already alluded to the former productiveness of the coal mines of Tallmadge, and have mentioned the fact that most of these mines are now abandoned; the basins of coal in which they were located having been practically exhausted. Considerable coal is, however, still produced in the township, and it is altogether probable that with proper search other basins will be discovered, from which its coal industry will be revived. The "Centre" and a large area north, south and east of it, lie considerably above the coal level, and, as the dip is south east, there are some localities where the horizon of the coal is nearly 150 feet below the surface. Over most of the district I have mentioned borings should be made to at least the depth of 100 feet before the search is abandoned. It should be remembered too, that the basins of Coal No. 1, are frequently narrow, and the territory will only be fairly tested by borings made at frequent intervals.

The principal centre of coal industry in the county at present, is in

Springfield and Coventry. Steer's mine, the mines of the Brewster Coal Co., and Brewster Brothers, and the Middlebury Shaft—all located near the line between the above mentioned townships—are now producing a large quantity of coal for shipment to Akron and Cleveland. The maximum thickness of the coal seam here is about 5 feet, and it thins out on all sides toward the margin of the basin. Doubtless here, as elsewhere, the basins of coal are connected, and future explorations will result in tracing such connection south and east into other important deposits.

The Johnson shaft, near the south line of Coventry, has already been alluded to. The coal from this mine is of superior quality, and resembles that of the Mahoning valley more than any before found in Summit County.

At the Franklin Coal Co.'s mine, in the northern part of Franklin, the coal is 4½ feet thick, of good quality, closely resembling that obtained at Massillon. It lies from 60 to 100 feet below the surface; the massive sand rock above it ranging from 40 to 50 feet in thickness. In the southwest corner of Franklin township the coal where opened is not as thick or as good as in the last mentioned localities. At Steer's new shaft in Coventry, the coal is 4½ feet thick, 90 to 110 feet from the surface, overlaid by 15 feet of black shale and from 30 to 40 feet of sandstone. Little coal has yet been mined here, but it seems to be of excellent quality. A section taken near the north line of Franklin township includes the following strata:

1.	Sandstone	40 to 60 feet.
2.	Shale	20 to 30 "
3.	Hard iron ore	1 "
4.	Coal	4½ "

Iron Ore. On the land of Mr. Thomas Britton, 1½ miles east of Middlebury, is an important deposit of iron ore, which I refer, with some hesitation, to the horizon of Coal No. 1. The drift from which the ore is taken exposes 4 feet of rock which includes a thickness of about 2 feet of ore. The analysis of this ore will be found on another page. Sherbondy Hill, west of Akron, is capped with the coal rocks, but gives no indication of any valuable deposit of coal. A band of iron ore, similar in character to that referred to above, but thinner, is exposed in this locality.

A sheet of the Coal Measures underlies the surface in the west part of Norton township, and a small area in Copley, but up to the present time no important coal strata have been found there. A boring made half a mile north of the centre of Norton revealed the following section:

1.	Earth	17 feet.
2.	Shale	16 "
2.	Conglomerate	75 "

All the borings made for coal in the township gives similar results; the Conglomerate being struck after passing through a thin bed of coal shale.

Coals No. 3 and 4. As has been stated, Coal No. 2 has no economic value in the county. Coal No. 3 lies beneath the lowest of the two limestones which are found in the southeastern corner of the county. It is well seen in the vicinity of Mogadore, at East Liberty, and between Greensburg and Greentown. At its northern outcrop, Coal No. 3 is thin, but it improves in quality toward the south and east. It is, however, doubtful whether it can be anywhere profitably worked in Summit County. Coal No. 4 lies from 25 to 40 feet above No. 3. It is also capped with limestone, which, like the lower one, has a thickness of from 2 to 4 feet, and is extensively burned for quicklime. Both these limestones carry calcareous, nodular or plate iron ore on their upper surfaces, but neither stratum seems to be of sufficient thickness to be worth working. Coal No. 4 near Greensburg, attains a thickness of from 4 to 5 feet. It is usually divided into two benches, of which the upper furnishes coal of good quality, the lower containing more sulphur. At Stripe's mine, near the southeast corner of Green township, and on Daniel Smith's land, near by, the coal has been mined many years for local consumption, and for burning lime. It has here a shale parting near the middle which impairs its value. Where opened east of this locality, near Greentown, the parting is thinner or absent, and the coal better. Indications of a similar change are giving by borings north of Greensburg, on lands of Mr. Johnson, and it seems probable that over a considerable area in this vicinity this coal may be profitably mined.

The place of the block coal (Coal No. 1) is from 150 to 200 feet below Coal No. 4, and hence all the southeastern corner of the county should be explored for basins of this coal. If the proposed railroad should be constructed from Cleveland to Akron, and thence to Canton, it will open up all this part of the county, and offer inducements for a thorough exploration of the territory underlaid by both coals No. 1 and No. 4. Being here on the summit of the water shed, with a down grade all the way to Cleveland, coal could be transported from this region to the Lake at a very small cost. With such facilities for the shipment of the coal, it will be worth while to explore all portions of the territory lying between the Tuscarawas and the eastern line of Green.

Fire-clay. The fire-clay which underlies Coal No. 3 has already become

one of the important elements of wealth to the county. This deposit, in parts of Summit County, is of unusual thickness and purity, making excellent stone-ware and fire-brick. It is estimated that there are produced from this stratum of clay in Springfield township alone, about one and a half millions of gallons of stone-ware each year; and a very large amount of the material is transported into other parts of the county and state. It is of interest to notice in this connection, that this bed of fire-clay is the same with that worked at Atwater, in Portage, and still more extensively in Columbiana County. Over how large an area in Summit County it maintains the dimensions and excellence it exhibits in Springfield, we have as yet no means of knowing. At East Liberty it is apparently of good thickness and quality, but in central and southern Stark County—where exposed in the valleys of the Nimishillen and Sandy—it is of less value. The Springfield clay is eminently plastic, and hence better fitted for stone-ware than fire-brick, but by mixing it largely with sand, and still better with the hard clay of Mineral Point, Mr. J. Parke Alexander, of Akron, has produced fire-brick scarcely inferior in quality to any other made in the state, or even any imported. To get the best results with this clay alone, in making fire-brick, it should be first ground, made into a paste, and this burned, then again coarsely ground and the fragments cemented with 1-6 to 1-10 of fresh plastic clay, moulded and burnt again.

The following analyses will convey some additional information in regard to the useful minerals of Summit County. They were made by Dr. Wormley, state chemist, with the exception of No. 4, which was made by Prof. W. W. Mather:

1. Peat, Coventry Peat Company, Coventry.

Ultimate composition in normal state.

Carbon	50.56
Hydrogen	6.43
Nitrogen	1.23
Sulphur	0.33
Oxygen	34.85
Ash	6.60
	100.00
Moisture	10.40
Consisting of Hydrogen	1.15
Oxygen	6.25

2. Coal No. 1, Johnson's shaft, Franklin township.
3. Coal No. 1, Franklin Coal Co., " "
4. Coal No. 1, D. Upson's mine, Tallmadge township.
5. Coal No. 3, Greentown, both benches.

	2.	3.	4.	5.
Specific Gravity	1.256	1.271	1.264	....
Water	2.70	3.40	5.067	3.25
Volatile combustible matter	37.30	36.10	39.231	38.75
Fixed Carbon	58.00	58.70	53.404	55.05
Ash	2.00	1.80	2.298	2.95
	100.00	100.00	100.00	100.00
Sulphur	0.93	0.799	0.549	1.73
Ash	White.	White.	....	White.
Coke	Compact.	Compact.	....	Compact.

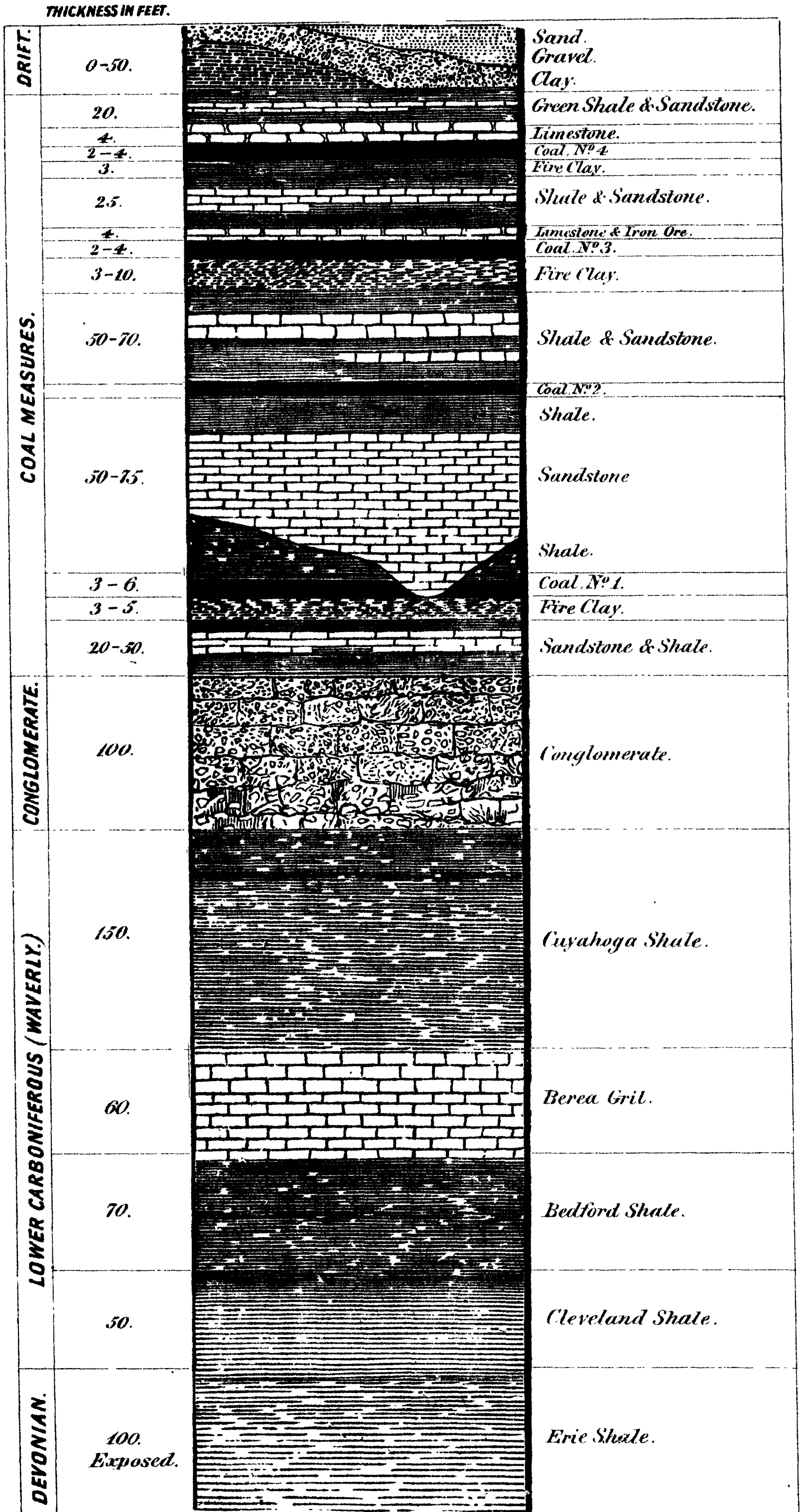
6. Iron Ore, H. Roberts, Middlebury.
7. Iron Ore, Over Coal No. 3, Greentown.

	6.	7.
Specific Gravity	3.333	3.342
Moisture combined	1.24	2.65
Silicious matter	21.08	12.23
Iron, Carbonate	58.76	70.68
" Sesquioxide	4.53	....
Alumina	1.00	0.40
Manganese	0.80	1.65
Lime, phosphate	1.81	....
" Carbonate	4.25	7.00
Magnesia "	5.22	5.54
Sulphur	0.41	0.17
Phosphoric acid	....	0.013
	99.10	100.333
Metallic iron	31.53	34.12
Phosphoric acid	0.83	0.013

8. Fire Clay, Mogadore.
9. " " East Liberty.

	8.	9.
Water (combined)	5.45	7.00
Silicic acid	70.70	62.00
Alumina	21.70	24.80
Iron	....	traces.
Lime	0.40	1.75
Magnesia	0.37	0.42
Potash and Soda	....	3.22
	98.62	99.39

SECTION OF THE ROCKS OF SUMMIT COUNTY.



Strobridge & Co. Lith. Cin.

REPORT

ON

SECOND GEOLOGICAL DISTRICT.

BY

E. B. ANDREWS.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—I herewith transmit, for publication in Volume I. of the Final Report of the Geological Survey of Ohio, detailed reports on the counties of Gallia, Meigs, Athens, Morgan and Muskingum; to which I add a brief discussion of some points involved in the study of the coal-field of south-eastern Ohio, enough matter, in all, to fill the space allotted to me in the volume.

My assistant in the field work and in preparing the Sheets of Grouped Sections, Mr. W. B. Gilbert, has rendered me invaluable aid, and I cannot commend his labors too highly.

Very truly, yours,

E. B. ANDREWS,
Assistant Geologist.

CHAPTER VIII.

REPORT ON GALLIA COUNTY.

This county has the Ohio river for its eastern border; for its southern, the river and Lawrence county; for its western, Lawrence and Jackson counties, and for its northern, Vinton and Meigs. The principal streams by which the county is drained, are the Raccoon, Symmes, Indian Guyandotte, Campaign, Kayger and Chickamauga creeks. The county lies wholly within the range of the Productive Coal Measures. The general surface is hilly. The soil is of fair quality. Several seams of limestone are found, but they are not very thick. The most persistent stratum has its geological position about 240 feet below the Pomeroy seam of coal. About 80 or 90 feet higher is another stratum, sometimes seen, which, as a general rule, has more fertilizing value than the lower one. This is due to its greater solubility under atmospheric agencies, and, because of this greater solubility, it is not so often seen upon the surface. There are, besides, other limestones, which are more local in their development, but exert a good fertilizing effect. The valleys, which have the "wash" of hillsides, containing any of these limestones, are generally rich. The best soil is that of the alluvial interval of the Ohio, which is very fertile. The climate of the county is mild and the county is well adapted to the raising of fruit. For vineyards and peach orchards almost any desirable elevation above the low valleys can be obtained.

The chief of its mineral resources is coal, but in some parts of the county this is far from being abundant. There are four workable seams of coal, two in the western part of the county and two in the eastern. The western coal seams are the Sheridan seam, and one about 50 feet higher. The eastern seams are the Pomeroy and the Jeffers seam, the

latter being about 45 feet below the former. Between these groups or pairs we have 260 feet of almost barren Coal-measures, consequently that part of the county in which these 260 feet are spread, constituting the surface, is destitute of coal. In the extreme western part of the county, in Greenfield township, we reach the Ferriferous limestone about 70 feet below the Sheridan seam of coal. Under this limestone is another seam of coal, and about 20 feet above it is the place of the New Castle seam, which is extensively mined in Lawrence county. The Sheridan seam has a fine development on Symmes creek and generally through Walnut and Greenfield townships. Analyses of this coal, given in another part of this Report, show the coal to be of superior quality. The Jeffers seam, so called from the mine in Clay township where it is worked, is a coal of fair quality and rich in heating power. The character of the Pomeroy seam is already well known. For the details of the information relative to these several coal-seams, the reader must refer to the Map of the Grouped Sections of the county, and to the Reports on the several townships.

The principal iron ores are to be found in the western part of the county, and were noticed, in part, in the *Second Annual Report.*

There is little doubt that brine of remunerative strength may be obtained by boring almost anywhere along the Ohio river. The wells would be a little less deep than at Pomeroy, and possibly the brine would be a little less strong. The question of cheap fuel would, however, be the chief question. In Cheshire, there is considerable coal in the hills, as will hereafter be shown.

GREENFIELD TOWNSHIP.

The more important geological facts obtained in this township were published in the *Second Annual Report.* A section was obtained on the lands of the Gallia Furnace Company, in Sec. 16, which will be found in Map IV., No. 5, in that Report. In this section are found the coal directly under the Ferriferous limestone, and the Sheridan coal about 70 feet higher. Another section obtained on Dry Ridge, showing the position of a valuable stratum of iron ore, was also published in the Report, and is seen in Map IV., No. 6. The ore is 114 feet above the Sheridan coal. The Sheridan coal is found on Dry Ridge.

In more recent investigations, a section was obtained on the land of J. L. W. Evans, in Sec. 13, in this township. It shows the following strata:

		FEET.	IN.
1.	Fossiliferous limestone	1	0
2.	Shale	8	0
3.	Laminated buff colored sandstone	8	0
4.	Sandstone	6	0
5.	Not exposed	150	0
6.	Soft disintegrating sandstone	20	0
7.	Shale	6	0
8.	Coal, 1 ft. 6 in. }		
9.	Clay, 0 " 4 " } Sheridan coal	4	2
10.	Coal, 2 " 4 " }		
11.	Clay	2	6
12.	Shale	35	0
13.	Reported coal in bed of Symmes creek.		

See Map VI., No. 3.

A sample of the coal from the Evans bank, taken from near the bottom of the lower and principal bench, was analyzed by Prof. Wormley, with the following result:

Specific gravity	1.295
Water	5.20
Ash	1.80
Volatile combustible matter	28.80
Fixed carbon	64.20
Total	100.00
Sulphur	0.79
Sulphur left in coke	0.38
Percentage of sulphur to coke	0.57
Permanent gas per pound in cubic feet	3.40

This shows a remarkably fine quality of coal. The ash is very small and the fixed carbon is unusually large. The sulphur is also not large. If the sample fairly represents the coal of the whole seam, the character of the coal is remarkably good. In regard to the dry-burning quality, I have little positive knowledge, but the coal is not regarded as a caking or cementing coal by those who have used it. If sufficiently dry-burning it will make a good furnace coal. If too soft and melting to be used in the raw state, it must first be coked for furnace use. From its geological position there must be a wide range of the Sheridan coal seam in this township. How extensive the ore found 114 feet above the coal is, I have no means of deciding, but as its stratigraphical place in the

series of strata can now be easily determined, the extent of the ore can readily be ascertained by those interested. Should a railroad be built through this township, the minerals will be found of great value.

WALNUT TOWNSHIP.

Reference was made to this township in the *Second Annual Report*, and a geological section, obtained in section 19, given. This section is seen in Map IV., No. 9, and the coal of the Jacob Webster bank was shown in Fig. 10, on page 180. The section is repeated in Map VI., No. 10. Analyses of Mr. Webster's coal were made by Prof. Wormley and given on page 181. In the same section 19, on John Shaib's land, the same seam of coal is seen, where it measures as follows:

	FEET.	IN.
1. Coal	0	8
2. Slate	0	3
3. Coal	4	6
4. Under clay	...	...

See Map VI., No. 6.

On the land of Charles Neal, in the same section, we find:

	FEET.	IN.
1. Shale, not measured	...	...
2. Coal, upper bench not opened	...	...
3. Slate	0	4
4. Coal	4	0
5. Clay	2	6

See Map VI., No. 7.

On the land of Mrs. Mary Proovens, Sec. 23, in this township, the following section was taken:

	FEET.	IN.
1. Shale	16	0
2. Coal, upper 6 in. cannel	1	6
3. Underclay and shale	6	0
4. Limestone	1	0
5. Shale	30	0
6. Fossiliferous limestone	1	0

See Map VI., No. 8.

The place of this seam of coal is about 150 feet above the Sheridan seam.

The following analyses of coal from Jacob Webster's new bank were made by Prof. Wormley:

No. 1. Sample taken 6 inches from bottom.
No. 2. Sample taken 2 feet from bottom.
No. 3. Sample taken 3 feet 6 inches from bottom.
No. 4. Analysis of lower bench in old bank, copied from former Report.
No. 5. Sample taken from Strait's bank, Waterloo.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Specific gravity	1.338	1.295	1.260	1.300	1.300
Moisture	4.40	5.30	5.70	5.15	7.30
Ash	6.00	4.50	5.30	4.60	1.90
Volatile combustible matter	29.20	31.70	30.90	29.65	30.90
Fixed carbon	60.40	58.50	58.10	60.60	59.90
Total	100.00	100.00	100.00	100.00	100.00
Sulphur	1.28	0.76	0.71	0.82	0.93
Sulphur remaining in coke	0.52	0.41	0.38	0.07	0.49
Per centage of sulphur to coke	0.78	0.61	0.59	0.11	0.79
Gas per pound in cubic feet	3.08	3.24	3.32	3.24	3.72

The average of fixed carbon in the new bank is 59 per cent., which is large, while the average per cent. of sulphur is 0.92, which is not large. The coal of the old bank appears to lose more of its sulphur in coking. The quality of the coal of the same seam from Strait's bank, Waterloo, is very superior. The ash is unusually small and the sulphur small, while the fixed carbon is large. The coal of this seam is very valuable, and if a railroad were built up the Symmes Creek valley, and westward to Cincinnati or Dayton, the coal could be advantageously shipped both to the Ohio river and to the Western markets.

In addition to the Sheridan seam of coal, found in this and adjacent townships, there is another seam about 50 feet higher, which, measured at one place by Mr. Gilbert, was found to be 3 feet 6 inches thick. The place of this coal is given in the geological section in Map IV., No. 9, of the *Second Annual Report,* and repeated in Map VI., No. 10, of this Report. Traces of this seam of coal have been found over a wide area, but Mr. Gilbert found few exposures of it where it could be measured. Prof. Edward Orton has recently made examinations along the proposed Symmes Creek railroad route. In his report to Col. W. H. Trimble, President Southern Ohio Railroad Company, dated October 22, 1872, I find the

following reference to this upper seam: "The upper seam, already alluded to, has an average thickness of four feet, and is of equal extent with the one above named. For a few square miles around Waterloo, it can be mined with even more facility than the lower vein. It is counted in this neighborhood as fully equal to the lower vein as a blacksmithing coal, but I have seen no analysis of it." In another place, Prof. Orton thus writes: "Two seams—nearly equal in thickness, extent and purity—occur in this district, separated from each other by an interval of fifty feet. I examined various outcrops of these seams through a belt of country, the area of which was not less than thirty square miles. After ascertaining that I had not traversed one-half of the ground occupied by them, I came to see that the supply in this coal-field alone is so vast that it might be drawn upon by south-western Ohio for centuries, without fear of exhaustion."

Prof. Orton suggests that this region be called the *Waterloo coal field*, the village of Waterloo being proximately in the centre of it. The designation is very suitable. The two seams would then be known as the upper and lower Waterloo seams. The more general term for the lower seam is the Sheridan seam.

The following analysis by Prof. Wormley of a sample of the coal of the Upper Waterloo seam, i. e., the seam 50 feet above the Lower Waterloo or Sheridan seam, shows a coal of unusually fine quality:

Specific gravity	1.304
Moisture	6.50
Ash	2.40
Volatile combustible matter	30.30
Fixed Carbon	60.80
Total	100.00
Sulphur	0.76
Sulphur left in coke	0.30
Percentage of sulphur to coke	0.47
Gas per lb. in cub. feet	3.80

This is the only analysis made of the coal of this seam, but it indicates a coal of such unusual excellence that the seam should be carefully explored by those interested.

The existence of the two seams, the upper and lower Waterloo, in the same hills, each so rich and pure, gives great prospective value to this region.

PERRY TOWNSHIP.

This township lies east of Greenfield and north of Walnut. It is drained by the Raccoon creek and its small tributaries on the east and north-east, and on the west and south-west by Symmes creek and its small branches.

Near Wales, a village in the north-west part of the township, the Sheridan seam of coal is mined on the land of Henry Hudson. The coal is about 3 feet thick. A blossom of another seam is seen 35 feet above, but the seam is probably quite thin. A geological section taken east of Wales, in Sec. 5, shows nothing of value except the Sheridan coal.

		FEET.	IN.
1.	Sandy fossiliferous limestone	2	0
2.	Sandy shale	14	0
3.	Hard sandstone, with a little iron ore	1	0
4.	Red shale	12	0
5.	Limestone	0	3
6.	Finely laminated bluish sandstone	25	0
7.	Compact sandstone	2	0
8.	Sandstone laminated at top, compact below	15	0
9.	Mostly clay shale	18	0
10.	Laminated sandstone	8	0
11.	Red shale with nodules of iron ore	9	0
12.	Sandstone	10	0
13.	Laminated sandstone	9	0
14.	Red shale	4	0
15.	Mostly laminated sandstone	36	0
16.	Blossom of coal	—	
17.	Fine grained laminated sandstone	15	0
18.	Heavy sandstone	20	0
19.	Coal—Sheridan seam	3	0

See Map VI., No. 4.

There is little coal to be expected in the hills in this township, which are composed of the strata lying above the Sheridan seam of coal.

On the land of John Bryan, Sec. 26, we find, on a very high hill, an out-lier of the Pomeroy seam of coal. The following detailed geological section was taken at this point:

		FEET.	IN.
1.	Sandstone	2	0
2.	Shale	10	0
3.	Black slate	0	10
4.	Coal	0	8
5.	Black slate	0	6
6.	Coal	0	

		FEET.	IN.
7.	Black slate	2	0
8.	Clay	0	8
9.	Black slate	0	6
10.	Coal	2	4
11.	Under clay	2	0
12.	Not exposed	240	0
13.	Fossiliferous limestone	2	0

See Map VI., No. 5.

The coal in the above section is the only coal mined for some miles around. The identification with the Pomeroy seam is determined by its having the proper and usual elevation above the lower fossiliferous limestone. This is well seen by reference to the map.

RACCOON TOWNSHIP

Lies north of Perry, and adjoins, on the west, Jackson county. The Raccoon creek runs through the eastern part of the township.

In the western part of the township we find the Sheridan coal. On the land of Thomas Morgan, Sec. 20, the coal seam measures 4 feet, with 2 feet of clay shale above, and over the shale 5 feet of sand rock. For this section, see Map VI., No. 12. The coal appears to contain more sulphur than at many other places.

On the land of J. S. Topping, Sec. 36, the following geological section was taken:

		FEET.	IN.
1.	Fossiliferous sandy limestone	3	0
2.	Sandstone, with shale above	25	0
3.	Not well exposed	14	0
4.	Finely laminated sandstone	21	0
5.	Coal, not now mined	1	6
6.	Not exposed	60	0
7.	Coal reported (Sheridan seam)	—	

See Map VI., No. 11.

On the land of C. S. Gooch, Sec. 26, a seam of coal, 1 foot 4 inches thick, was found with 8 feet of sand rock directly above it. This is the same as the upper coal on Mr. Topping's land. Its place is given in Map VI., No. 13.

On the land of John Lloyd, near Centreville, the following geological section was obtained:

		FEET.	IN.
1.	Sandstone	12	0
2.	Coal, Sheridan seam	2	10
3.	Underclay	3	0
4.	Sandstone, upper part laminated, lower part crumbling	20	0

		FEET.	IN.
5.	Hard sandstone	3	0
6.	Shale	3	0
7.	Black shale	1	0
8.	Blue iron ore (siderite)	0	3
9.	Shale	5	0
10.	Sandstone	2	0
11.	Shale	3	0
12.	Coal	1	0
13.	Underclay and shale	15	0

See Map VI., No. 2.

Considerable coal for local use has been taken from Mr. Lloyd's land, and also from the bank of Thomas Morgan. These banks supply Centreville and the adjacent region.

Near Adamsville there is a copious out-flow of brine from an old oil well.

HUNTINGTON TOWNSHIP.

This township is situated in the north-western corner of the county and is drained by the waters of Raccoon and Little Raccoon creeks.

Reference was made to this township in the *Second Annual Report*, and a geological section, taken in Sec. 7, given. This section appeared in Map III., No. 37. I copy the section:

		FEET.	IN.
1.	Blue clay shale, rich in coal plants	6	0
2.	Coal, upper 8 in. slaty, comparatively little pyrites	4	0
3.	Not exposed	50	0
4.	Iron ore	1	0
5.	Ferriferous limestone	4	0

If the coal given in the above section is the Sheridan coal, there was probably a mistake in the measurement of the space between it and the limestone.

The Ferriferous limestone with its ore is seen only in the western part of this township. It dips to the east, or a little south of east, and soon goes below the beds of the streams. In other parts of the township, we have the Sheridan coal.

In Sec. 21, the Sheridan coal presents the following structure:

		FEET.	IN.
1.	Shale	8	0
2.	Slaty coal	1	6
3.	Clay parting	0	2
4.	Coal	3	0

See Map VI., No. 1.

So far as observed, the quality of the coal was not equal to that of the same seam further south.

At many points in this part of the State we find another seam of coal from 50 to 60 feet above the Sheridan seam, and in Wilkesville township, Vinton county, there are two seams still higher. It is probable that some of these seams may be found hereafter in Huntington township. But, generally, in Gallia county there is an interval of about 260 feet, between the seam 50 feet above the Sheridan seam in Walnut township, and the seam 45 feet below the Pomeroy seam found in the eastern part of the county, which is barren of productive coal seams.

MORGAN TOWNSHIP.

This township is situated upon the north line of the county, between Huntington on the west and Cheshire on the east. It is drained chiefly by Campaign creek, except its western border, which is drained by Raccoon creek. In Sec. 7, on the land of Wm. E. Shaver, the following geological section was taken:

		FEET.	IN.
1.	Laminated sandstone	10	0
2.	Red shale containing nodules of limestone	16	0
3.	Sandstone	20	0
4.	Blossom of coal	...	...
5.	Under-clay	2	0
6.	Laminated sandstone	20	0
7.	Red shale with nodules of siderite ore	12	0
8.	Fossiliferous limestone	3	0
9.	Shale	1	0
10.	Coal, probably quite thin	...	...
11.	Shale	10	0
12.	Hard fine-grained sandstone	3	0
	Bed of Campaign creek.		

See Map VI., No. 14.

The fossiliferous limestone in this section is one of very extensive range through the Second Geological District. It is found in a large number of counties. At Athens, in Athens county, it is seen in the bank near the bridge over the Hocking river, not far from the station of the M. & C. railroad. It is found in the hills near Cambridge, in Guernsey county. Its place is generally about 225 feet below the Pomeroy seam of coal, but in Gallia county the interval by the measurements was about 15 feet greater, and is so given on the Map. But possibly there may have been a slight mistake in the measurements, as it is almost impossible to be perfectly accurate if there be any considerable horizontal distance be-

tween the two exposures. In all such cases allowance must be made for dip, which is generally an unknown quantity. From 80 to 85 feet above this limestone we find another fossiliferous limestone, the place of which is proximately 140 feet below the Pomeroy coal. The interval is a little more in Gallia county. This upper limestone—which I have called the Ames limestone from a location in Ames township, Athens county, where Doctor Hildreth, while engaged in the old Geological Survey, observed it—is seen in Map VI., Nos. 3 and 4. On the land of Gilbert Glen, Sec. 31, in Morgan township, the lower limestone is seen with 1 foot 2 inches of coal below it, separated by one foot of shale. The coal has been mined a little. The same coal is mined at Frank Denney's, Sec. 19.

SPRINGFIELD TOWNSHIP.

This township lies directly south of Morgan and west of Addison.

In Sec. 29, on the land of A. J. Powell, we find the lower white fossiliferous limestone and the usual thin coal under it. The section is:

		FEET.
1.	White fossiliferous limestone	1
2.	Clay shale	1
3.	Coal	1

See Map VI., No. 15.

The limestone has been burned for lime, but little use has been made of the coal. On the land of James Cardwell, Sec. 23, we find:

		FEET.	IN.
1.	Shale not measured	...	...
2.	Slaty cannel coal	4	0
3.	Coal	0	6
4.	Not seen	35	0
5.	Fossiliferous limestone	...	...

See Map VI., No. 17.

In the eastern part of the township we find the Pomeroy seam of coal 245 feet above the white fossiliferous limestone. A geological section was taken on the land of Mr. Irwin, Sec. 6, as follows:

		FEET.	IN.
1.	Sandstone	20	0
2.	Laminated ferruginous shale	6	0
3.	Coal	0	2
4.	Black ferruginous slate	0	2
5.	Coal, Pomeroy seam	2	6

6.	Not exposed	248	0
7.	Fossiliferous limestone	...	...

See Map VI., No. 18.

GREEN TOWNSHIP.

This township lies south of Springfield, and directly west of Gallipolis. The Pomeroy seam of coal is found in the hills, but nowhere is very thick. We find also a seam,—which in Clay township is considerably mined, and which I have called the Jeffers coal,—the stratigraphical place of which is from 40 to 45 feet below the Pomeroy seam.

On the land of Mrs. Madeline Thompson, Sec. 5, the following geological section was taken:

		FEET.	IN.
1.	Sandstone	10	0
2.	Shale	3	0
3.	Coal, Pomeroy seam	2	3
4.	Not exposed	81	0
5.	Limestone, not measured	...	...
6.	Not exposed	82	0
7.	Red shale with nodules of limestone	20	0
8.	Limestone conglomerate, no fossils seen	3	0

See Map VI., No. 16.

The Jeffers coal was not seen, but its outcrop may easily have been covered up.

On the land of John Northrop, Sec. 19, the following geological section was taken:

		FEET.	IN.
1.	Sandstone, not measured	....	...
2.	Shale	8	0
3.	Coal, Jeffers seam	2	8
4.	Not exposed	130	0
5.	Shale	18	0
6.	Limestone	2	0
7.	Buff laminated sandstone	4	0
8.	Red shale	16	0
9.	Nodules of ore and limestone	...	...
10.	Shale	30	0
11.	Fossiliferous limestone	2	6
12.	Dark shale	4	0
	Bed of Raccoon creek.		

See Map VI., No. 19.

The same seam of coal as that given in the above section is mined on the land of Mr. Gilligan, in the same Sec. 19.

HARRISON TOWNSHIP.

This township lies south of Green and east of Walnut. The higher lands take the Jeffers coal-seam, but nowhere are the valleys in the western part of the town deep enough to reach down to the Sheridan coal, or even to the seam 50 feet above it. Like several other townships in this county, it is not in the best geological range for coal.

On the land of Wm. Williams, Sec. 33, a geological section was taken, which is as follows:

	FEET.	IN.
1. Blue shale with nodules of siderite ore	8	0
2. Coal	0	2
3. Clay	0	2
4. Coal	1	6
5. Under-clay and shale	10	0
6. Limestone	1	0

See Map VI., No. 9.

The limestone in this section is not to be confounded with a fossiliferous limestone, the place of which is 25 feet below. The coal in this section has not been found as yet in much thickness, but its exact place in the series being known,—and this is easily ascertained by reference to Map VI.,—further search might be rewarded by finding it somewhere sufficiently developed for profitable working. In Sec. 18, on the land of James Bane, we find the Jeffers seam of coal pretty well developed. The geological section is as follows:

	FEET.	IN.
1. Roof not seen	...	...
2. Coal, not mined	2	6
3. Black slate	1	0
4. Clay shale	2	0
5. Coal	3	2

On the land of Jacob Day, Sec. 8, we find the same seam presenting the following measurements:

	FEET.	IN.
1. Black slate	1	2
2. Coal	0	5
3. Clay	0	10
4. Coal	3	0

GUYAN TOWNSHIP.

This township extends to the south line of the county, and touches the Ohio river on the south-east. It is chiefly drained by the waters of Indian Guyandotte creek.

The chief coal seen in this township is the Jeffers seam, the geological position of which is about 50 feet below the Pomeroy seam. The following geological section was taken on the land of Samuel Holley, section 18:

		FEET.	IN.
1.	Blossom of Pomeroy coal	...	...
2.	Not exposed	39	0
3.	Shale	8	0
4.	Black slate	0	6
5.	Coal, Jeffers seam	2	8
6.	Under-clay and sandstone	12	0
7.	Not exposed	32	0
8.	Fire-clay colored with iron	15	0

See Map VI., No. 20.

Here the blossom of the Pomeroy seam was seen, but no measurements of the coal could be made. The seam is probably thin.

On the land of William Caldwell, section 17, the following geological section was taken:

		FEET.	IN.
1.	Sandstone and conglomerate	15	0
2.	Not exposed	12	0
3.	Shale	4	0
4.	Black slate	0	6
5.	Coal, Jeffers seam	3	4
6.	Under-clay and shale for the most part	10	0
7.	Limestone	1	0
8.	Not exposed	30	0
9.	Fire-clay colored with iron	8	0

See Map VI., No. 21.

Here the coal reaches a fair thickness. In section 13, on the land of Elijah Williams, the same seam of coal is seen, but it is much thinner. The geological section is as follows:

		FEET.
1.	Sandstone and conglomerate	25
2.	Clay shale	6
3.	Coal, Jeffers seam	2
4.	Not seen	220
	Ohio river.	

On the land of Franklin Fowler, section 13, was taken the following geological section:

		FEET.	IN.
1.	Sandstone and conglomerate	12	0
2.	Shale	8	0
3.	Coal, Jeffers seam	2	6
4.	Not exposed	10	0
5.	Limestone	1	0
6.	Not exposed	35	0
7.	Unstratified fire-clay colored with iron	4	0
8.	Not exposed	51	0
9.	Sandstone	20	0

See Map VI., No. 22.

The same coal is mined on the land of Burwell Simms, in the same section. The somewhat remarkable deposit of fire-clay found everywhere in this region, about 45 feet below the Jeffers coal, may have value. It doubtless has too much iron in it for good fire-brick, but there may be other uses to which it may be applicable.

OHIO TOWNSHIP

Lies east of Guyan, and is bounded on the east and south by the Ohio river. The Jeffers seam of coal is mined near Sample's Landing. A geological section was taken on the land of C. R. Small, as follows:

		FEET.	IN.
1.	Sandstone, not measured	...	...
2.	Coal, Pomeroy seam, reported	1	
3.	Not exposed	30	
4.	Sandy shale	8	
5.	Clay shale	2	
6.	Coal, not mined	2	
7.	Black ferruginous shale	3	
8.	Coal	0	10
9.	Clay	1	
10.	Coal, Jeffers seam	3	
11.	Under-clay	2	6
12.	Not exposed	40	0
13.	Fire-clay stained with iron, not measured	...	...

See Map VI., No. 23.

This coal is mined at two other banks near this landing. It is of the same thickness in all. The coal has a good reputation.

CLAY TOWNSHIP

Is directly north of Ohio township, and lies upon the Ohio river. In this township, the Raccoon creek empties into the Ohio, after draining portions of Hocking, Athens, Vinton, Meigs, Jackson and Gallia counties.

The principal coal found in this township is the Jeffers seam, which is mined by Abram Jeffers, Sec. 26. A geological section was taken at his mines as follows:

		FEET.	IN.
1.	Sandstone not measured	...	...
2.	Coal, Pomeroy seam, once opened	1	6
3.	Not exposed	30	0
4.	Sandy shale	10	0
5.	Clay shale	3	0
6.	Top coal, not mined	2	0
7.	Ferruginous black slate	2	0
8.	Coal	0	10
9.	Clay	1	0
10.	Coal	3	6
11.	Under clay	2	6
12.	Not exposed	33	0
13.	White fire-clay	4	0

Bed of creek.

See Map VI., No. 24.

The fire clay—No. 13 in the above section—contains apparently little iron, and may be worthy of trial for fire-brick. The clay has not been analyzed.

Samples of the Jeffers coal were analyzed by Prof. Wormley, with the following result:

No. 1. Taken 14 inches from bottom of seam.
" 2. " from middle of seam.
" 3. " " near the top of seam.

	No. 1.	No. 2.	No. 3.
Specific gravity	1.281	1.300	1.304
Moisture	5.10	3.20	5.30
Ash	3.20	7.70	6.20
Volatile combustible matter	32.90	31.60	26.70
Fixed carbon	58.80	57.50	61.80
Total	100.00	100.00	100.00
Sulphur	2.35	2.74	0.87
Sulphur left in coke	1.12	1.37	0.46
Percentage of sulphur to coke	1.80	2.01	0.67
Permanent gas per lb. in cubic feet	3.48	3.32	3.32

The coal near the top of the seam is unusually good, but the seam, taken as a whole, contains too much sulphur to warrant the use of the coal for those purposes where sulphur is specially detrimental. The coal has high heating power and ought, if as good as the sample tested, to make a good steam coal.

On the land of Hugh Plyman, Sec. 5, the Jeffers coal was seen with its accompanying strata as follows:

	FEET.	IN.
1. Sandstone	12	
2. Shale	3	
3. Black slate and shale	3	0
4. Not well exposed	3	0
5. Coal, Jeffers seam	2	6
6. Under clay	1	0
7. Impure hard sandy limestone	3	0

See Map VI., No. 25.

GALLIPOLIS TOWNSHIP.

Unfortunately neither of the two seams of coal found in the eastern part of the county—viz., the Pomeroy seam and the Jeffers seam, 45 to 50 feet below the Pomeroy seam—appears to be well developed in the immediate vicinity of Gallipolis. To the south in Clay, Ohio, Harrison and Guyan townships, the Jeffers seam is thick enough to be valuable, and to the north, in Cheshire, the Pomeroy seam is in fair thickness, but in the hills near Gallipolis both seams appear to be quite too thin to have much practical value. Judging beforehand, one would think that to be located along the direct range of a famous seam of coal, like the Pomeroy seam,—which is also the Wheeling and the Pittsburgh seam — would almost insure an adequate supply of fuel, the first element of modern material progress, but this is often not the case. Coal seams show very great variations both in thickness and quality, and the Pomeroy seam is no exception to this law. In the ancient coal-producing marsh there were areas where very little vegetable matter was accumulated, and consequently in such areas the coal would be thin. There were even areas in which no vegetation grew, and where we find no coal whatever. If, in the series of maps accompanying the *Geological Reports* for the Second District, some of which are not yet published, we follow the Pomeroy seam of coal through Gallia, Meigs, Athens, Morgan, Washington, Noble Muskingum, Guernsey and Belmont counties, we shall find the seam subjected to the most remarkable variations. Over very large areas it is so thin as to be utterly worthless.

The following is a geological section, or two sections combined, each taken in the neighborhood of Gallipolis:

		FEET.	IN.
1.	Sandstone, not measured	—	—
2.	Red shale	10	0
3.	Sandstone	9	0
4.	Shale	8	0
5.	Coal (Pomeroy seam)	2	0
6.	Under-clay	2	0
7.	Sandstone	2	0
8.	Shales and sandstone	20	0
9.	Not exposed	17	0
10.	Sandstone	10	0
11.	Coal (Jeffers seam)	1	3
12.	Clay and shale	4	0
13.	Sandy iron ore	0	6
14.	Laminated ferruginous sandstone	10	0
15.	Not exposed	56	0
16.	Red shale, with sandy shale in the middle	20	0

See Map VI., No. 26.

It is possible that by careful search one or the other of these coal seams might be found in larger development.

The ore noticed in the foregoing section was analyzed by Prof. Wormley, with the following result:

Specific gravity	2.682
Water combined	10.00
Silicious matter	47.20
Iron sesquioxide	36.23
Manganese	1.80
Lime phosphate	0.41
" carbonate	2.28
Magnesia	1.51
Sulphur	trace.
Total	99.43
Metallic iron	25.36
Phosphoric acid	0.19

The ore is good, so far as freedom from impurities is concerned, but it is not rich enough in metallic iron to make its use profitable, unless, possibly, as a mixture with the richer Missouri ores.

ADDISON TOWNSHIP

Is situated upon the Ohio river north of Gallipolis. In this township the Pomeroy seam of coal is found but it is not very thick. On the land of Wesley Rothgeb, Sec. 17, the following geological section was taken:

		FEET.	IN.
1.	Heavy sandrock	25	0
2.	Shale	2	6
3.	Coal, Pomeroy seam	2	0

On the adjacent Sec. 23, on the land of Samuel Rothgeb, the coal is a little thicker. The measurements were as follows:

		FEET.	IN.
1.	Heavy sandrock	20	0
2.	Shale	2	0
3.	Coal, Pomeroy seam	2	6

This section is seen on Map VI., No. 30.

The Jeffers seam was not noticed in this township. It is probably very thin or has disappeared altogether.

CHESHIRE TOWNSHIP.

This township lies in the north-east corner of the county and borders Rutland on the north and a part of Salisbury on the east. Both of these townships are in Meigs county; the latter contains the city of Pomeroy. Cheshire is better supplied with coal than any township in the eastern part of Gallia county.

At Bradbury's bank, Sec. 16, near Kaygerville, the following geological section was taken:

		FEET.	IN.
1.	Sandy Shale	8	0
2.	Shale	2	0
3.	Coal, Pomeroy seam	4	6
4.	Under-clay	1	0
5.	Not seen	140	0
6.	Limestone, no fossils seen	1	0
7.	Blue shale	10	0
	Bed of Kayger creek.		

See Map VI., No. 27.

This is a good development of the Pomeroy seam. In Sec. 9, on the land of Jacob Rife, we find the Pomeroy coal seam measuring 4 ft. 2 in., with 30 feet of heavy sandrock over it. No shale was seen over the coal. This section is seen in Map VI., No. 28.

On the land of David Coughenoeur, Sec. 8, was taken the following geological section:

		FEET.	IN.
1.	Heavy sandstone	30	0
2.	Shale	1	6
3.	Coal, Pomeroy seam, somewhat unevenly bedded	4	4
4.	Under-clay and shale	5	0
5.	Not exposed	41	0
6.	Sandy ore and sandstone	4	0

See Map VI., No. 29.

The Pomeroy seam was found to be 4 feet thick on the land of John Q. Evans, Sec. 3. Here we find 3 feet of shale between the coal and the heavy sandrocks above.

The Evans and Guthrie banks furnish the main supply to the eastern half of Cheshire township.

ELEVATION AND DIP OF COAL SEAMS.

I am indebted to Major Henry Grayum, Civil Engineer of Gallipolis, for many valuable statistics, the result of his own personal surveys. They were communicated by him to the *Gallipolis Bulletin*, Feb. 14, 1872.

In his article, he designates the Pomeroy seam as Coal No. 1 and the Jeffers seam as Coal No. 2. His statement in regard to the dip is as follows: "Seam No. 1, in the N. E. quarter of Sec. 33, Town. 6, Range 14, (near Braley's salt well, Rutland township, Meigs county,) has an elevation of 284 feet above high water of the Ohio; and near the south-east corner of Sec. 35, Town. 3, Range 14, (Gallipolis township) it has an elevation of 192 feet above the same mark. Allowing 8 feet for fall of river between the two points, and we have 200 feet elevation at the latter point, leaving 84 feet (the difference) to be divided by 16½, the number of miles of *latitude*, which gives 5.09 feet of dip south to the mile. In the N. W. quarter of Sec. 1, Town. 1, Range 13, (Minersville, Meigs county,) the same seam is at high water mark. Deducting 10 feet from the elevation at Braley's well for the two miles of north latitude, and adding two feet for fall of the river between the points, and we have 276 feet of difference, which, divided by 10¼, the number of miles of east departure, gives 26.926 feet to the mile for the dip *east*, the direct line of dip being south 73° 7′ east. A line at right angles with this line of the greatest dip would bear north 16° 53′ east and south 16° 53′ west, and would neither rise nor dip. From this calculation, we may assume 5.09 feet *south* and 26.926 feet *east* as the empirical law of the dip of the seam." This, Major Grayum says, will require correction for variation (2°) of needle, inaccuracies of directions and distances of old survey lines, and also for any undulations there may be in the seam. The highest elevation of the

Pomeroy seam, as given, is at Braley's salt well, and the lowest is at Antiquity, above Pomeroy, where the coal is reached by a shaft. Major Grayum gives the elevations of these points above tide water at Norfolk, as 840 and 377, respectively. The difference, 463, is the whole amount of dip between the two points. Calling the direct distance 17 miles, we have an average dip of 27.23 feet per mile in this particular direction.

The interval between the Pomeroy seam (No. 1) and the Jeffers seam (No. 2), taking the average of all Major Grayum's measurements, is 43.8 feet. Major G. has also noticed the thin seam of coal which appears in Map VII., Nos. 8 and 9, and gives its position as 200 feet below the Pomeroy seam, which is exactly what the Map shows.

REGISTER OF SECTIONS IN GALLIA COUNTY.

MAP VI.

No.		
1.	Geological Section	in Sec. 21, Huntington township.
2.	"	on land of John Lloyd, near Centreville, Raccoon township.
3.	"	on land of J. L. W. Evans, Sec. 13, Greenfield, township.
4.	"	in Sec. 5, Perry township.
5.	"	on land of John Bryan, Sec. 26, Perry township.
6.	"	on land of John Shaib, Sec. 19, Walnut township.
7.	"	on land of Charles Neal, Sec. 19, Walnut township.
8.	"	on land of Mrs. Mary Proovens, Sec. 23, Walnut township.
9.	"	on land of Wm. Williams, Sec. 33, Harrison township.
10.	"	in Sec. 19, Walnut township.
11.	"	on land of J. S. Topping, Sec. 36, Raccoon township.
12.	"	on land of Thomas Morgan, Sec. 20, Raccoon township.
13.	"	on land of C. S. Gooch, Sec. 26, Raccoon township.
14.	"	on land of Wm. E. Shaver, Sec. 7, Morgan township.
15.	"	on land of A. J. Powell, Sec. 29, Springfield township.
16.	"	on land of Mrs. Madeline Thompson, Sec. 5, Greene township.
17.	"	on land of James Cardwell, Sec. 23, Springfield township.
18.	"	on land of Mr. Irwin, Sec. 6, Springfield township.
19.	"	on land of John Northrop, Sec. 19, Greene township.
20.	"	on land of Samuel Holley, Sec. 18, Guyan township.
21.	"	on land of William Caldwell, Sec. 17, Guyan township.
22.	"	on land of Franklin Fowler, Sec. 13, Guyan township.
23.	"	on land of C. R. Small, Sample's Landing, Ohio township.
24.	"	on land of Abram Jeffers, Sec. 26, Clay township.
25.	"	on land of Hugh Plyman, Sec. 5, Clay township.
26.	"	in neighborhood of Gallipolis, Gallipolis township.
27.	"	Bradbury's bank, Sec. 16, Cheshire township.
28.	"	on land of Jacob Rife, Sec. 9, Cheshire township.
29.	"	on land of David Coughenoeur, Sec. 8, Cheshire township.
30.	"	on land of Samuel Rothgeb, Sec. 23, Addison township.

CHAPTER IX.

REPORT ON MEIGS COUNTY.

This county lies upon the Ohio river, which constitutes its eastern and part of its southern boundary. It is bounded on the north by Athens county, on the west by Vinton county, and in part on the south by Gallia county. The principal affluents of the Ohio, by which the county is drained, are Shade river and Leading creek. The county is generally hilly. The soil of the valleys is rich, and that in the immediate valley of the Ohio particularly so. When it is remembered how crooked the Ohio river is along the border of this county, and how much of this very rich valley soil therefore belongs to the county, the average fertility of the county cannot be very low. The county is wholly within the limits of the Productive Coal Measures, and is rich in coal, the well known Pomeroy seam having here a large development and extending over a large area. The peculiar curvature of the Ohio river in the vicinity of Pomeroy exposes a very large frontage for the most easy and profitable mining. The county is also rich in saliferous strata, from which brine for the most extensive salt works of the state is obtained. The brine at Pomeroy is obtained by boring not far from a thousand feet below the Pomeroy seam of coal. It is sometimes something more this, but in all cases, I have no doubt, that the brine is obtained in the Upper Waverly sandstone. The three needed conditions for profitable salt-making are found upon the Ohio river in Meigs County, viz: brine of required strength and in ample supply; coal, at the minimum cost, for fuel; and cheap water transportation to markets. There is scarcely a limit to the amount of salt which might be made in Meigs County.

The general dip of the strata in the county is a little south of east, but the amount of the dip shows considerable variation.

Before concluding these preliminary remarks, it is proper for me to acknowledge the many obligations, under which Mr. Gilbert and myself have been placed, to Hon. M. Heckard, Civil and Mining Engineer, Pomeroy, for much valuable aid and information while we were prosecut-

ing the survey in this county. We are also indebted for the knowledge of many important facts to Hon. V. B. Horton, whose name will ever remain honorably conspicuous for his successes in the development of the mineral wealth of Meigs county.

SALEM TOWNSHIP.

This township is the south-west corner township of the county. It is bordered on the west by Wilkesville township, of Vinton county, in which township geological sections were made in 1870, and published in the Report for that year. The western part of Salem is drained by Strong run, a branch of Raccoon creek, the northern and eastern part by Leading creek, and the southern part by the headwaters of Campaign and Kayger's creeks.

On the land of Samuel Lyell, Sec. 8, a fossiliferous limestone was seen with a seam of cannel coal above it. The following is the section taken at this point:

		FEET.	IN.
1.	Bituminous shale	8	0
2.	Cannel Coal, somewhat slaty	2	0
3.	Interval, not seen	12	0
4.	Limestone, fossiliferous	1	0

This group is seen in Sec. No. 6, Map VII.

The same limestone and coal are seen on the land of R. S. Gray, Sec. 6, where two sections were made by Mr. Gilbert. One of these sections reveals:

		FEET.	IN.
1.	Limestone, bluish, no fossils seen	8	0
2.	Not exposed	53	0
3.	Blossom of coal, reported thickness	2	0
4.	Interval, not exposed	16	0
5.	Limestone, bluish, fossiliferous	3	0

See Sec. No. 4, Map VII.

The other section is as follows:

		FEET.	IN.
1.	Sandrock, in heavy ledge	30	0
2.	Not exposed	60	0
3.	Clay shale	4	0
5.	Coal	1	0
6.	Shale	0	2
7.	Coal	1	0
.	Not exposed	60	0
9.	Fossiliferous limestone	3	0

See Sec. No. 5, Map VII.

In the same section and township, the coal of the last section was seen on the land of J. Saxon, sixty feet above the fossiliferous limestone, which is a good geological guide for the neighborhood.

The section on Mr. Saxon's land is as follows:

		FEET.	IN
1.	Shale	10	0
2.	Coal	1	2
3.	Clay	0	11
4.	Coal, reported 2 feet, 1 foot seen	2	0
5.	Not exposed	60	0
6.	Limestone, whitish, fossiliferous	2	0

See Sec. No. 3, Map VII.

From these sections it will be seen that there are two seams of coal a little more than 40 feet apart, neither of which is thick enough for very profitable mining, but sufficiently so to furnish a local supply for family use.

The upper of these seems must not be confounded with the Pomeroy seam, which is about 160 feet higher. Wherever the hills are high enough to take the Pomeroy coal, it should be found in its proper geological horizon.

COLUMBIA TOWNSHIP

Lies north of Salem, and is drained by the head-waters of Leading creek, with the exception of the north-west corner, which is drained by Raccoon creek. A section was made at Slater's Mill, Sec. 36, which revealed the following strata:

		FEET.	IN.
1.	Yellow shale (estimated)	30	0
2.	Gray limestone, fossiliferous	1	3
3.	Sandstone and shale	47	0
4.	Blossom of coal	...	...
5.	Sandstone and shale	62	0
6.	Buff limestone (no fossils seen)	...	...
7.	Sandstone and shale	60	0
8.	Kidney ore, not measured	...	...
9.	Blossom of coal	...	...
10.	Interval to bed of Raccoon creek, estimated	30	0

If the gray fossiliferous limestone of the above section is the equivalent of a fossiliferous limestone found in Meigs and Athens counties, the place of the Nelsonville or Mineral City coal will be not very far below the bed of the creek at Slater's Mill. Possibly some oil well bored in this neighborhood may have passed through it. The above section is not given upon the Map.

On the land of Mr. J. C. Swett, in Fraction 17, the following section was made:

		FEET.	IN.
1.	Limestone, fossiliferous	1	0
2.	Not exposed	18	0
3.	Blossom of coal	...	...
4.	Sandstone	15	0
5.	Coarse sandstone and conglomerate	12	0
6.	Coal	2	6
7.	Shale	0	2
8.	Coal	1	6

For this section see Sec. No. 1, Map VII.

In Sec. 8, in the same township, near Henry Rollins', the strata were seen as follows:

		FEET.	IN.
1.	Hard blue limestone, no fossils seen	2	0
2.	Not exposed	54	0
3.	Buff sandy shale and nodular limestone containing *Chonetes* and other mollusks	10	0
4.	Not exposed	70	0
5.	Whitish fossiliferous limestone	2	0
6.	Not exposed	25	0
7.	Coarse sandstone and conglomerate	30	0

For this section see No. 2, Map VII.

SCIPIO TOWNSHIP

Lies east of Columbia. It is drained chiefly by the Mud fork of Leading creek and by Little Leading creek. The Pomeroy seam of coal is found in the township, but is pretty high in the hills. At the Wells coal bank, a mile east of Pageville, the following measurements were made:

		FEET.	IN.
1.	Sandrock seen	20	0
2.	Shale with coal plants	4	0
3.	Coal	3	6

About a mile south-west of Pageville we find an exposure of:

		FEET.	IN.
1.	Reddish shale with nodular limestone	5	0
2.	Buff sandy shale, calcareous and containing nodules of limestone, *Chonetes*, *Crinoids*, &c	9	0

This group is 139 feet in vertical distance below the Pomeroy seam of coal. For the whole of the above strata see No. 7, Map VII.

Near Harrisonville in the same township we find the Pomeroy coal showing the following sub-division:

		FEET.	IN.
1.	Shale roof	...	...
2.	Coal	0	6
3.	Clay	1	0
4.	Coal	2	1
	To this add,		
5.	Not seen in detail	143	0
6.	Sandy shale and fossiliferous limestone	9	0
	For this see Sec. No. 8, Map VII.		

The interval between the Pomeroy coal and the calcareous group, 143 feet below, is chiefly filled with clayey shales. During past ages these shales have been easily and largely removed by the erosive action of the streams, and as a consequence we find the valleys wide and smooth, and everywhere presenting a beautiful appearance. The land naturally needs lime, and I think it might be applied everywhere to soils made from the shales of this geological horizon with very great profit.

RUTLAND TOWNSHIP

Lies south of Scipio and east of Salem. It is drained by Leading creek and Little Leading creek, the latter emptying into the former a little below the village of Rutland. The valleys of these streams are beautiful.

The following interesting section of strata was made at Braley's Salt Well, Sec. 33:

		FEET.	IN.
1.	Sandstone (not measured)	...	...
2.	Shale	1	0
3.	Coal, somewhat slaty	1	0
4.	Clay shale	1	6
5.	Coal, Pomeroy seam	3	8
6.	Not exposed	10	0
7.	Sandrock in heavy ledge	20	0
8.	Not exposed	92	0
9.	Clay shale	25	0
10.	Sandy ferruginous limestone containing *Chonetes*, &c	1	0
11.	Reddish clay shale, with occasional siderite ore and limestone	35	0
12.	Sandstone	37	0
16.	Not exposed	16	0
17.	Limestone, fossiliferous	2	0
18.	Not exposed	22	0
19	Coarse sandrock at top, passing down into conglomerate	30	0
20.	Not seen	1	0
21.	Stain of coal	...	...
	For this section see No. 9, Map VII.		

Near McMaster's mill, Sec. 26, the following exposure of the strata was seen:

		FEET.	IN.
1.	Coal, reported thickness	1	6
2.	Clay shale	20	0
3.	Limestone, ferruginous and fossiliferous	2	0
4.	Clay shale	4	0
5.	Sandstone, with *Sigillaria, &c.*	2	0
6.	Sandy shale	5	0
7.	Hard blue sandstone in bed of Leading creek	...	...

For this section, see No. 10, Map VII. The coal of this section is 205 feet below the Pomeroy serm.

On the land of Mr. Seth Payne, Sec. 8, the following section was taken:

		FEET.	IN.
1.	Sandstone, thickness not seen	...	...
2.	Shale	10	0
3.	Slaty coal, } Pomeroy seam	1	6
4.	Slate, } Pomeroy seam	0	3
5.	Coal, } Pomeroy seam	4	9
6.	Not seen	18	0
7.	Shale with nodules of siderite ore	18	0
8.	Sandstone	14	0
9.	Red shale	19	0
10.	Nodular limestone	2?	...
11.	Shale with scattered nodules limestone near the top	50	0
12.	Not exposed	82	0
13.	Blossom of coal	...	...
14.	Not exposed	18	0
15.	Limestone, fossiliferous	2	0
16.	Sandy shale	24	0
17.	Bed of Leading creek	...	...

Sec. No. 12, Map VII.

On the land of Mr. John Stiff, Sec. 3, in this township, the Pomeroy seam of coal presents the following structure:

		FEET.	IN.
1.	Coal	0	6
2.	Slate	0	6
3.	Coal	1	0
4.	Slate	0	4
5.	Coal	1	0
6.	Slate	0	6
7.	Coal	4	6
8.	Shale	1	0
9.	Coal	0	8

This is shown in Sec. No. 11, Map VII.

About a mile and a half north of Rutland village, on the land of Mr. H. Holt, an oil well was bored, several years since, to the depth of 1030 feet. Very heavy lubricating oil flows from the well at the rate of one barrel a week. The oil doubtless comes from the Waverly sandstone. I was unable to obtain a record of the strata passed through in boring the well. Since my visit to this township, I have been informed by Hon. S. N. Titus, that by the explosion of a torpedo in this well, the flow of oil has been increased to between three and four barrels a day.

SALISBURY TOWNSHIP

Is situated upon the Ohio river, and contains the city of Pomeroy and town of Middleport.

A section taken at Pomeroy, shows the following strata:

		FEET.	IN.
1.	Red shale on top of hill back of Court House	...	...
2.	Not exposed	58	0
3.	Shale	6	0
4.	Laminated sandstone	6	0
5.	Clay shale	10	0
6.	Sandstone	16	0
7.	Not exposed in detail	31	0
8.	Red shale	6	0
9.	Compact sandrock	9	0
10.	Shale	18	0
11.	Heavy sandrock	64	0
12.	Sandy shale, with coal plants	9	0
13.	Top coal, } Pomeroy seam	1	0
14.	Slate, } Pomeroy seam	0	2
15.	Coal, } Pomeroy seam	4	0
16.	Bituminous shale with streaks of coal	1	2
17.	Fire clay	1	0
18.	Fine grained sandstone	8	0
19.	Shale	6	0
20.	Sandstone	2	0
21.	Shale	14	0
22.	Sandstone	2	0
23.	Shale	16	0
24.	Sandstone	2	0
25.	Shale	8	0
26.	Not seen to low water of Ohio river	30	0

See No. 16, Map VII.

On Sugar run, Pomeroy, we find the seam of coal presenting the same structure as in the last section. There are 8 feet of arenaceous shale, containing coal plants, between the coal and the heavy sandrock above.

At Coalport we find the coal and its associated strata as follows:

		FEET.	IN.
1.	Heavy sandrock, not measured	—	—
2.	Shale, ferruginous, containing coal plants	12 to 17	0
3.	Bituminous shale	0	8
4.	Coal	1	6
5.	Coal	3	7
6.	Underclay and shale	6	0
7.	Sandstone, fine grained	4	0
8.	Yellow shale	5	0

For this Sec. see No. 17, Map VII.

Near the mouth of Leading creek, the following section was taken:

		FEET.	IN.
1.	Sandrock	65	0
2.	Coal	1	6
3.	Coal	3	0
4.	Underclay and shale	9	0
5.	Limestone, impure and sandy	2	0
6.	Sandstone	2	0
7.	Shale	10	0
8.	Sandstone	5	5
9.	Shale	12	0
10.	Sandstone	4	0
11.	Buff and red shale, containing nodules of limestone	18	0

For this Sec. see No. 18, Map VII.

At Hart's coal mine, in Fraction 2 in this township, the Pomeroy coal and associated strata are as follows:

		FEET.	IN.
1.	Heavy sandrock, not measured	—	—
2.	Shale	2	0
3.	Top coal	1	6
4.	Coal	4	0

ANALYSIS OF POMEROY COAL.

Prof. Wormley has analyzed a sample sent from Pomeroy with the following result:

Specific gravity	1.358
Moisture	4.10
Ash	5.90
Volatile combustible matter	33.90
Fixed carbon	56.10
Total	100.00

Sulphur	0.46
Sulphur left in coke	0.38
Percentage of sulphur to coke	0.61
Gas per lb. in cub. ft	3.55
Color of ash	Light yellow.
Coke	Compact.

This analysis shows an excellent quality of coal, possibly better than we may expect the whole seam to possess. Should, however, the sample analyzed fairly represent the larger part of the seam, the coal is certainly worthy of trial for some of the higher uses. Such coal ought to make a pure coke adapted to almost all metallurgical operations. It is possible, however, that the coke may be too tender to endure great pressure of weight or of blast. A good coke is a great desideratum in Ohio. In some seams of coal, the very best of the coal is, in mining, converted into fine coal and slack, which, by washing, is fitted for the coke oven, and thus made into valuable coke. Even the old slack piles in the neighborhood of Pittsburgh are being thus utilized and converted into coke for the blast furnace. By the process of washing, the slate, and the sulphur so far as it is combined with iron in a segregated form, would sink, leaving the lightest and purest coal to be collected for the coke oven. If by this method coal could be obtained of purity equal, or even proximately equal, to the sample analyzed by Prof. Wormley, it would make a coke of greater purity, so far as the sulphur element is concerned, than that made from the Connellsville coal of Pennsylvania. If properly coked, it might perhaps be of sufficient strength for the blast furnace. For the generation of steam, and for household uses, the Pomeroy coal has long been used and is held in good repute. Besides supplying the salt-furnaces and rolling mills, and other home wants, the coal is largely shipped to the lower markets on the Ohio river. The coal is not regarded as a desirable gas coal, but, in the sample analyzed, the amount of gas is considerable and the sulphur in small quantity. If an adequate supply of coal of the same quality could be obtained, it is worthy of a careful trial for gas-making. No determination has been made of the illuminating power of the gas. The top coal is generally inferior to the rest of the seam.

With additional facilities for transportation of salt and other manufactured articles, Pomeroy is destined to become one of the most important manufacturing places in the West. The production of salt is already very large. In connection with the salt-works, a new and interesting branch of industry has sprung up of late, in the manufacture of bromine. This is made from the bittern, or liquid, remaining after the salt has been precipitated. This liquid, which formerly ran to waste, is now sold to the bromine manufacturers, and is a source of considerable income to

the salt companies. Bromine is so successfully and largely made, at Pomeroy, as to cheapen, it is said, the price of this important chemical agent all over the world.

BEDFORD TOWNSHIP

Lies north of Salisbury. It is drained by West Shade river and its branches. The Pomeroy seam of coal extends through this township, maintaining generally a good working thickness.

In Fraction 7 the following section was obtained:

		FEET.	IN.
1.	Red shale	12	
2.	Not exposed	21	0
3.	Blossom of coal	...	...
4.	Red shale	14	0
5.	Shale with small nodules of limestone	9	0
6.	Shale	24	0
7.	Sandstone	30	0
8.	Shale	15	0
9.	Sandrock	60	0
10.	Shale	2	0
11.	Coal, Wm. Castleton's bank	3	6

This is the Pomeroy seam. A blossom of coal is seen 152 feet above the Pomeroy seam. For this section, see No. 14, Map VII.

In Sec. 8, of this township, we find the following grouping:

		FEET.	IN.
1.	Sandrock	65	0
2.	Shale, with blossom of coal near the top	10	0
3.	Coal, slaty at top	4	0
4.	Under-clay and clay shale	8	0
5.	Fragments of limestone	2	0
6.	Bed of Shade river	...	...

See Sec. No. 15, Map VII.

At Storey's coal bank, in Sec. 17, in this township, we find:

		FEET.	IN.
1.	Heavy sandrock, not measured	...	...
2.	Shale	6	0
3.	Coal, somewhat slaty	0	8
4.	Coal, Pomeroy seam	3	6

Sec. No. 13, Map VII.

On Fraction 23, we find the following strata;

		FEET.	IN.
1.	Sandstone, laminated	8	0
2.	Shale	4	0
3.	Bituminous shale	0	10
4.	Clay shale	1	0
5.	Coal, Pomeroy seam	3	0

SUTTON TOWNSHIP.

At Minersville, about two miles above Pomeroy, on the Ohio river, the following section was taken:

		FEET.	IN.
1.	Laminated sandstone	20	0
2.	Limestone and sandstone commingled	4	0
3.	Not exposed	15	0
4.	Red clay shale	18	0
5.	Not exposed	92	0
6.	Heavy sandrock	70	0
7.	Shale	2	0
8.	Top coal, } Pomeroy seam	1	6
9.	Coal, } Pomeroy seam	3	0
10.	Interval to low water in Ohio river	48	0

Sec. No. 19, Map VII.

At Syracuse, Sutton township, we have the following section:

		FEET.	IN.
1.	Red shale	18	0
2.	Sandstone	15	0
3.	Clay shale	27	0
	Top of mining slope.		
4.	Sandrock to low water of Ohio river	59	0
5.	Same sandrock below low water level	14	0
6.	Shale	2	0
7.	Coal, Pomeroy seam	4	8

Sec. No. 20, Map VII.

The slope is excavated in the heavy sandrock.

A careful section was made at a point about a mile north of Bowman's run, which revealed the contents of the hill for 211 feet above the top of the heavy sandrock overlying the Pomeroy coal. Nothing was found except alternating sandstones and shales.

About three and a half miles a little north of east of Racine, on land formerly owned by Mr. LaBlanc, is found a seam of coal of somewhat in-

different quality, reported to be 3 feet thick. The geological position of this coal is about 336 feet above the Pomeroy seam. Sec. No. 23, Map VII.

LETART TOWNSHIP.

This township lies in a remarkable bend or ox-bow of the Ohio river. It is in the western part of this bend that the Letart falls, so well known to Ohio river men, are found. The falls are mere rapids formed by the passage of the river over a comparatively hard stratum of sandrock. No special examination of the locality was made, and hence it is impossible to determine just which of the strata it may be. The rock bed extends entirely across the river.

At Antiquity, in this township, a shaft 198 feet deep has been sunk to reach the Pomeroy seam of coal. Here the section is as follows:

		FEET.	IN.
1.	Top of shaft to low water mark of Ohio river	62	0
2.	From low water to top of heavy sandrock	50	0
3.	Heavy sandrock	70	0
4.	Shale with coal plants	10	0
5.	Coal, } Pomeroy seam	2	5
6.	Slate, } Pomeroy seam	0	1
7.	Coal, } Pomeroy seam	3	3
8.	Hard fine-grained sandstone	12	0
.	Fire-clay	5	0

Sec. No. 22, Map VII.

Here the coal is 130 feet below the low water level of the Ohio river. At Pomeroy, the coal in the hill behind the Court House is 90 feet above the low water level. The distance between the two points in a straight line is very nearly eight miles. The average fall of the Ohio river, according to Col. Charles Ellett, Jr., is $5\frac{218}{1000}$ inches per mile. If we call the fall 6 inches per mile, the absolute dip of the coal seam is 216 feet, or at the rate of 27 feet per mile. The direction, as obtained from the locations on the Meigs County Map is, proximately, south 49° east. The dip from Syracuse to Antiquity is a little less than from Pomeroy to Syracuse, the former being a trifling fraction over 25 feet, and the latter being about 29 feet 9 inches. But since in our hurried barometrical measurements we may not have been perfectly exact in our work, these figures can be regarded as only proximately correct.

LEBANON TOWNSHIP.

The upper coal found in Sutton township, which is 336 feet above the Pomeroy seam, is found in Lebanon, near the mouth of Old Town creek,

where it has been opened on the land of Mr. Coe. It is here 160 feet above the Ohio river. The coal is reported to be 3 feet thick and of good quality. The blossom of the same seam was seen on the land of David Eaton, a mile and a half north-east of the mouth of Old Town creek.

CHESTER TOWNSHIP.

At Adams' Mill, on Shade river, in the north-eastern portion of Chester township, the following section was made:

		FEET.	IN.
1.	Shale	50	0
2.	Sandstone	3	0
3.	Shale	8	0
4.	Coal, reported thickness	2	0
5.	Clay and shale	5	0
6.	Sandstone and conglomerate	49	0
7.	Siderite ore in nodules, not measured	...	...
8.	Shale	46	0
9.	Sandstones and interstratified shales	35	0
10.	Interval to bed of Shade river	30	0

Sec. No. 21, Map VII.

This coal is believed to be the equivalent of the seam found in Sutton and Lebanon, the geological place of which is about 336 feet above the Pomeroy coal. The conglomerate of the last section is quite persistent, it showing itself, in its proper horizon, east and north of Adams' Mill.

ORANGE AND OLIVE TOWNSHIPS.

Nothing of economic value was seen in these two townships. The Pomeroy seam of coal is below the surface. These and the other eastern townships of Meigs county unfortunately contain very little limestone. In the eastern counties of this Geological District, as, for example, Belmont, we find limestones in great abundance above the horizon of the Pomeroy seam of coal, this seam having been traced through Athens, Morgan, &c., to the Ohio river at Bellair. But where in Belmont county we find limestones, in Meigs county we find only sandstones and shales. This shows that the conditions of rock-making in the ancient ocean were very different in the two areas at the time the strata above the coal were deposited.

REGISTER OF MEIGS COUNTY.

MAP VII.

No.
1. Geological Section on land of J. C. Swett, Frac. 17, Columbia township.
2. " on land of Henry Rollins, Sec. 8, Columbia township.
3. " on land of J. Saxon, Sec. 6, Salem township.
4. " on land of R. S. Gray, Sec. 6, Salem township.
5. " on land of R. S. Gray, Sec. 6, Salem township.
6. " on land of Samuel Lyell, Sec. 8, Salem township.
7. Two sections combined, near Pageville, Scipio township.
8. Geological Section near Harrisonville, Scipio township.
9. " at Braley's Mill, Sec. 33, Rutland township.
10. " at McMaster's Mill, Sec. 26, Rutland township.
11. " of coal on land of John Stiff, Sec. 3, Rutland township.
12. " on land of Seth Payne, Sec. 8, Rutland township.
13. " at Storey's coal bank, Sec. 17, Bedford township.
14. " in Frac. 7, Bedford township.
15. " in Sec. 8, Bedford township.
16. " taken in Pomeroy on hill behind Court House, Salisbury township.
17. " at Coal-port, Salisbury township.
18. " near the mouth of Leading creek, Salisbury township.
19. " at Minersville, Sutton township.
20. " at Syracuse, Sutton township.
21. " near Adams' Mill, north-eastern part of Chester township.
22. " of coal-shaft at Antiquity, Letart township.
23. " in Sutton township, 3½ miles north-east of Racine.

CHAPTER X.

REPORT ON ATHENS COUNTY.

In our explorations in this county we have been placed under many obligations to Mr. John Ackley, of Athens, who, as Civil Engineer and Surveyor, has great familiarity with the physical geography of the county, and with the more important locations of minerals. In former years, much valuable information has been obtained from Hon. E. H. Moore, of Athens, whose knowledge of the general features of the county is unusually full and accurate.

This county, like all the counties in this part of the State, is hilly. The soil in many parts is naturally rich and fertile. In the valley of the Hocking it is peculiarly so, and hardly less so in some smaller valleys where limestone is abundant in the bordering hills. The county is well drained by the Hocking river and its affluents, and by the waters of the Raccoon and Leading creeks and Shade river. When the streams flow through regions where the strata are comparatively soft shales, we find broad and beautiful valleys, such as are seen on Margaret's creek and Federal creek; but where the heavy sandrocks prevail the streams have eroded for themselves only comparatively narrow channels. One of the most interesting and remarkable of examples of this is seen on Long run in Lodi township.

The county lies wholly within the productive Coal-Measures, and is well supplied with coal of excellent quality. The best known coal-field is in the north-west part of the county, in York township, where the Nelsonville seam is largely mined. In Trimble we find upon its western edge the same seam, which is thought to extend in its eastern dip beneath both Trimble and Dover. In this township, and in Dover, we find the so called Bayley's run seam, and in several townships in the north-eastern and eastern part of the county we have the Pomeroy seam. Other less

important locations of coal will be mentioned in connection with the several townships.

There are two well defined and persistent seams of fossiliferous limestone which extend through many townships. Their positions in the geological series are about 140 and 225 feet, respectively, below the Pomeroy seam of coal. The upper one I have called the *Ames limestone*, from its being well seen in Ames township. This limestone extends through a large number of counties. The lower limestone has an equally wide extent, but its largest and best development is in Guernsey county, and I have called it the *Cambridge limestone.* Besides these, there are in the eastern part of the county non-fossiliferous limestone deposits of very considerable vertical thickness, but generally their horizontal range is limited. They contribute to the fertility of the soil.

By reference to the Map of Grouped Sections the stratigraphical positions of all the leading rocks of the county will be readily seen. In Athens county the strata have a well marked dip to the east, or to a point a little south of east. Mr. W. H. Jennings, Civil Engineer of the C. & H. V. R. R., has taken the elevation of the Nelsonville seam of coal at many points in Athens, Hocking and Perry counties. It is hoped hereafter to obtain the elveations on the Newark, Somerset & Straitsville railroad, on the Atlantic & Lake Erie, and on the Cincinnati & Muskingum Valley railroads, so that a series of triangles may be worked out for the dip of the Nelsonville seam all along its outcrops from the Marietta and Cincinnati railroad to Zanesville. The careful determination of the dip in this way will be of great scientific and practical interest.

YORK AND WATERLOO TOWNSHIPS.

In the *Reports* for 1869 and 1870, the more important geological facts observed in York and Waterloo townships were presented. The Nelsonville seam of coal, with its associated strata, was traced through these townships. The quantity of Nelsonville coal mined is rapidly increasing, and the popularity of the coal widely extending. The strata gradually dip in a direction a little south of east. This is readily seen by the range of the Nelsonville coal, which at Nelsonville is in the hillside, while, at a point a little below the mouth of Monday creek, it dips below drainage; at Salina it is 100 feet below the surface, and at Athens about 200 feet below. Other similar illustrations of the dip might be given. There are many local undulations of the strata which make the dip irregular and often puzzling.

The only new discovery in Waterloo township is a seam of coal in the

bed of Rock Camp run in Sec. 19. This coal is 2 feet 10 inches thick, and has over it 10 feet of laminated sandrock. It is 125 feet below the flinty limestone, and about 50 feet above the Nelsonville seam of coal. It may be the equivalent of the Middle or Norris coal of Upper Sunday creek, Perry county. The coal appeared to contain considerable bi-sulphide of iron. The place of this coal is seen in Sec. 9, Map No. VIII. In Sec. 4. of this township, the Nelsonville seam, 6 feet thick, is found 108 feet below the surface.

DOVER TOWNSHIP.

At Salina and Chauncey, in this township, considerable salt is made from brine obtained from wells bored down into the Waverly sandstone. Coal for the salt furnaces is brought up by shafts from the Nelsonville seam, which is about 100 feet below the surface of the Hocking valley. So far as I can learn, a heavy sandrock, similar to that found over the coal at Nelsonville, overlies the coal in these shafts. On Meeker run, in York township, no such sandrock is found over the coal, but shales instead, and in these shales a seam of coal is found about 30 feet above the Nelsonville seam. Near the level of the alluvial surface of the valley, at Chauncey, is found a seam of coal, which was formerly worked to some extent and which is generally called the Bayley's run coal. This seam is found almost everywhere in its proper geological horizon through Dover and Trimble townships.

In Sec. 18, in this township, the Bayley's run coal was seen with a group of strata overlying it, as given below:

		FEET.	IN.
1.	Limonite ore	0	4
2.	Shale	9	0
3.	Limestone, fossiliferous, (Cambridge limestone)	2	0
4.	Laminated sandstone	20	0
5.	Not exposed	2	0
6.	Blossom of coal	...	...
7.	Not exposed	59	0
8.	Sandstone	8	0
9.	Shale	7	0
10.	Coal	1	9
11.	Clay parting	0	3
12.	Coal	2	4
13.	Under-clay	...	...

Sec. No. 5, Map VIII.

The following analysis of a sample of coal from C. Southerton's bank Sec. 34, was made by Prof. Wormley:

Specific gravity	1.309
Moisture	4.20
Ash	2.60
Volatile combustible matter	35.20
Fixed carbon	58.00
Total	100.00
Sulphur	1.04
Sulphur left in coke	0.41
Percentage of sulphur in coke	0.67
Gas per lb. in cubic ft.	3.97
Color of ash	Gray.
Coke	Compact.

This shows a very excellent coal. The ash is small and the fixed carbon is large, and the amount of gas is also large. The coal loses so much of its sulphur in coking that the coke is relatively free from it. If the sample analyzed represents the seam, or a considerable part of it, the coal is worthy of careful investigation as a coking coal. A good coke is a great desideratum in this part of Ohio.

On the land of Mr. L. Weethee, "Mount Auburn," Sec. 18, in Dover township, the following section was made:

		FEET.	IN.
1.	Fossiliferous limestone, (Ames limestone)	1	10
2.	Sandstones and shales not seen in detail	85	0
3.	Blue fossiliferous limestone, (Cambridge limestone)	1	4
4.	Not exposed	23	0
5.	Blossom of coal	...	...
6.	Not exposed	74	0
7.	Coal, } Bayley's run seam	1	4
8.	Clay parting, } Bayley's run seam	0	2½
9.	Coal, } Bayley's run seam	2	8
10.	Clay	3	6
11.	Nodules of siderite ore	...	...

Sec. No. 4, Map VIII.

The nodules of siderite in the clay, under the Bailey's run coal, are often quite large. On the land of Col. J. S. Jennings, Sec. 7, Trimble township, there is a fine show of this ore. One nodular mass measured 1 foot 6 inches in diameter. Considerable blende, an ore of zinc, was seen in some of the nodules. These nodules are not in close contact, but are mixed with clay and shale.

TRIMBLE TOWNSHIP.

This township is chiefly drained by Sunday creek and its branches. Snow fork of Monday creek runs along the west line of the township. On this fork, not far above the stream, the Nelsonville seam of coal, from six to ten or eleven feet thick, is everywhere found, but as this seam dips to the east, it is not to be met with above surface drainage in Trimble township, east of Snow fork. By means of shafts, however, much of the coal of this important seam might be mined and find an outlet by means of Snow fork valley. I have found a seam of coal on Snow fork, 45 feet above the Nelsonville seam, which, where once opened, is reported to be 4 feet thick. Mr. Gilbert, my assistant, found the blossom of a coal seam 45 feet above the latter, but I have nowhere found it opened. On the land of Bayliss Glenn, on Snow fork, not far from the line of Trimble township, two seams of coal were found above the Nelsonville seam, as given in the *Geological Report* for 1869.

Several sections were taken in this township. On the land of James Rutter, Sec. 10, the Bayley's run coal was found measuring 4 ft. 8 in., with 10 feet of sandstone over it. At a distance of 175 feet above this sandstone, or 185 feet above the coal, was seen a fossiliferous limestone, which is found to have a very wide range, and lies 140 feet below the Federal creek or Pomeroy coal. This limestone I have called the Ames limestone. This section on Mr. Rutter's land is seen in Sec. No. 3, Map VIII.

On the land of Mr. Newton, Sec. 11, the following geological section was taken:

			FEET.	IN.
1.	Limestone, fossiliferous, (Ames limestone)		1	0
2.	Not exposed except some coarse sandrock and conglomerate at the bottom		100	0
3.	Not exposed		23	0
4.	Shale		15	0
5.	Blossom of coal		...	...
6.	Not exposed		23	0
7.	Sandstone		15	0
8.	Shale and sandstone interstratified		6	0
9.	Shale, hard and blue		7	0
10.	Coal,	Bayley's run seam	1	5
11.	Slate parting,	Bayley's run seam	0	1½
12.	Coal,	Bayley's run seam	2	9

Sec. No. 2, Map VIII.

The following is the result of the analysis of the Bayley's run coal from Trimble township, from the land of James Rutter :

No. 1. Sample from near the bottom of seam.
" 2. " " " middle "
" 3. " " " top "

	No. 1.	No. 2.	No. 3.
Specific gravity	1.301	1.264	1.381
Water	5.00	4.80	4.50
Ash	7.40	3.40	3.40
Fixed carbon	55.30	56.60	54.60
Volatile combustible matter	32.30	35.20	37.50
Total	100.00	100.00	100.00
Sulphur	1.85	1.26	2.96
Sulphur left in coke	0.42	0.69	1.89
Gas, cubic feet per lb	3.27	3.42	3.12
Coke	Compact.	Compact.	Compact.
Ash, color	Fawn.	Reddish.	Red.

This is a fair coal. For household use and for the generation of steam it will serve an excellent purpose. The coal may also prove valuable for its coke. The coal of the lower and middle portions, parts with its sulphur in coking to the degree that the coke might be used in the blast furnace for a mixture, with other coal. The coke is very firm, a characteristic of the coke of this seam of coal generally.

The following analyses were made of samples of coal from the Bayley's run seam, taken from the following places in Trimble township:

No. 1. R. Stover's bank, Sec. 23, Trimble.
" 2. Chapalear's " " 7, "
" 3. Allen's " Fraction 2, "

	No. 1.	No. 2.	No. 3.
Specific gravity	1.300	1.280	1.291
Moisture	3.10	3.60	3.40
Ash	4.80	2.60	5.90
Volatile combustible matter	36.90	35.00	34.40
Fixed carbon	55.20	58.80	56.30
Total	100.00	100.00	100.00
Sulphur	3.54	1.29	1.09
Sulphur left in coke	1.70	0.49	0.60
Percentage of sulphur in coke	2.83	0.79	0.96
Gas per lb. in cubic feet	3.72	3.84	3.84
Color of ash	Fawn.	Gray.	Gray.
Coke	Compact.	Compact.	Compact,

Should No. 2 fairly represent the whole seam, there can be little doubt of the great value of this coal, where a coking coal is desired. If the coke is firm and compact, as we have reason to expect, this coal may meet a want long felt in this part of the state. So large a part of the sulphur passes off in coking, that the coke contains only 0.79 per cent. of this deleterious substance. This is much less than the Connellsville, Pennsylvania, coke contains, for samples of the latter, obtained at the Columbus Iron Works, were found by Prof. Wormley to contain 2.17 per cent. In No. 3, we find less sulphur in the raw coal but rather more in the coke, but this coke is also very good, and careful investigations should be made of both of these coals in order to ascertain their exact practical value as sources of coke.

In a recent trial boring at the Chapalear well, in Sec. 7, in this township, the following strata were reported by Rev. J. P. Weethee:

		FEET.	IN.
1.	Surface clay and sand	10	4
2.	Coal, Bayley's run seam	4	8
3.	Fire-clay	2	4
4.	Clay shale, lower part bituminous	6	2
5.	Shale, with thin layers of flag	13	0
6.	Limestone	2	10
7.	Sandy shale	14	0
8.	Dark limestone	3	0
9.	Blue shale	13	0
10.	Hard slaty shale	4	0
11.	Light shale, with some grit	11	0
12.	Blue sandy shale	17	
13.	Brown shale	1	6
14.	Coal, Nelsonville seam	8	4
15.	Fire-clay	1	0

The following is Prof. Wormley's report of his analysis of coal from the Nelsonville seam, reached by boring at the Chapalear well:

Specific gravity	1.303
Moisture	4.10
Ash	5.50
Volatile combustible matter	32.90
Fixed carbon	57.50
Total	100.00
Sulphur	0.79
Sulphur left in coke	0.49
Percentage of sulphur in coke	0.77
Gas per lb. in cubic feet	3.56
Color of ash	Dull white.
Coke	Compact.

This analysis reveals a most excellent coal. The percentage of sulphur is small. I see no reason why the coal is not adapted to all the higher uses. Should this famous seam of coal prove to extend under Trimble township, with an average thickness equal to that at this boring, and of equal quality, the fact will be of the greatest interest and consequence to this part of the State.

I have received from Rev. J. P. Weethee, of Dover township, a statement of the mineral resources along the lower Sunday creek valley and its tributaries, from which I copy many valuable facts. "About 35,000 acres of land in Trimble and Dover townships are drained by Sunday creek and its tributaries. A vertical plane drawn from the mouth of the creek to the north-east corner of Sec. 12, Trimble township, and extending downwards to the fire-clay under the Nelsonville seam of coal, would divide the surface into two nearly equal parts. That the Nelsonville seam of coal, or that great seam which sweeps around the area under consideration on the west, north-west and north, and is also known as the Straitsville seam and the "great vein" of the upper Sunday creek valley, extends beneath the surface under this area, is established by the following facts: First: This seam, so far as it is exposed along its extensive line of outcrop, is continuous and uniform, and maintains its parallelism with the seams higher up in the geological series. The inference is, therefore, that it must have an extension in the direction of its dip corresponding to that of the overlying and parallel seams. Second: All the shafts sunk in the western division of the district under examination,—none have been sunk in the eastern,—have penetrated this seam. Third: More than twenty wells bored for salt or oil in this district have perforated it. A trial well bored this fall in Section 7, Trimble township, passed through the seam. Its existence in the lower Sunday creek valley is therefore established.

"*Depth Below the Surface.* At Chauncey, where the seam is worked, it is 100 feet. At the mouth of Sunday creek it is about 85 feet below the water level. At the wells on Green's run, and also at the trial wells recently bored in Sec. 7, Trimble township, it is 80 feet, which is about the average depth in the valley of lower Sunday creek and its western tributaries. East of Sunday creek, it becomes gradually deeper as the dip, about 30 feet per mile, is eastward.

"*Thickness of the Seam.* Along its western and north-western outcrop the seam ranges from 6 to nearly 13 feet, and is opened at Nelsonville, Straitsville, Shawnee and on Upper Sunday Creek. On Snow fork of Monday creek, which runs nearly on the west line of Trimble township, the seam ranges from 6 to 11 feet. The proximity of these latter exposures

to the district under consideration gives these measurements much significance. At the trial boring in Sec. 7, Trimble township, completed December 6, 1872, the seam was found to be 8 feet 4 inches thick. North and north-west of this point the seam is known to thicken, reaching its maximum development on the upper Sunday creek and at Straitsville, in Perry county. The *quality of the coal* must be similar to that of the same seam at Nelsonville, Straitsville, &c. The expense of shafting will be but little more than that of drifting at the points where the seam is now mined.

"The next seam above the great seam crops out everywhere along the lower Sunday creek, and is regular in position and uniform in thickness. At the mouth of the creek it is 5 feet above low water, and at the north-east corner of Sec. 12, Trimble township, it is 4½ feet above low water. It is worked at five points in Dover township and eleven in Trimble on or west of Sunday creek. More than 50 years ago boat loads were taken down the Hocking and Ohio rivers to Cincinnati. This seam supplies coal for the whole lower Sunday creek valley. It appears along all the western tributaries and can be mined advantageously through the whole western half of the district under discussion. Its thickness will be seen from the following measurements, (the clay parting is to be deducted from the total thickness):

Locations.	Coal.		Clay parting.	
	Ft.	In.	Ft.	In.
Mouth of Sunday creek	4	6	0	2
Bailey's run, Fraction 34	4	6	0	2–2½
Greene's run, Sec. 19, Trimble	4	8	0	2½
Weethee's bank, Sec. 12, Dover	4	7	0	2
Johnson's bank, Frac. 18, Trimble	4	9	No part'g.	
Allen's bank, Frac. 2, Trimble	4	8	No part'g.	
Newton's bank, Sec. 5, Trimble	4	6	0	2
Henry Edward's bank, Sec. 24, Trimble	5	3	0	2
Richard Stover's bank, Sec. 23, Trimble	4	6	No part'g.	

"About 30 feet above, is another seam, varying from 10 inches to 4 feet in thickness. Near the head of Johnson's run, Sec. 36, Trimble, it is 4 feet thick. Near the eastern boundary of this coal-field the Federal creek seam appears.

"The value of the seam first above the great seam is not yet ascertained, as it has not yet reached the general market. Where known, it is very popular for household uses and for blacksmithing. It is much more

bituminous than the Nelsonville or Straitsville coal. Its future may place it among the most useful of our coal seams.

"*Iron Ore.* The iron deposits on the lower Sunday creek valley are similar in quality, and perhaps, equal in quantity, to those in the territory drained by its head waters. There are three distinct horizons of ore which we have traced from the mouth of Sunday creek to the Perry county line. The first underlies the Bayley's run or five feet seam of coal. It is in nodules mostly, and is a blue carbonate of iron or siderite. It is exposed in many localities and seems to contain a large percentage of iron. At Zimmerman's mill, west branch, Sec. 17, Trimble, there is, perhaps, the richest display of ore in this district. It is found in a bluish yellow shale and consists of four continuous layers, each from six to eight inches thick. The second horizon of ore is found under the next seam of coal above, and is imbedded in shales. There are indications of a considerable amount of ore. The third horizon of ore is under the third seam of coal. The ore is in round nodules and is a siderite or blue carbonate of iron. It resembles the ore found under the great seam of coal on the farm of B. Sanders, Monroe township, Perry county. The quantity is less than that found in the horizon under the Bayley's run coal, first mentioned.

"In Sec. 7, Trimble township, there is a layer of ore lying in blocks, which has been exposed to a depth of about three feet. It is a siderite, with a slight admixture of sand on the surface of the blocks. It is the heaviest deposit yet noticed. Its geological position is about 20 feet above the first or Bailey's run seam of coal. On further investigation, other deposits may be found, but these are the principal layers yet discovered.'

AMES TOWNSHIP

Lies directly east of Dover. This township is drained by the Federal creek and its branches. The township was named by the first settlers, who were from New England, and probably earnest Federalists, after Fisher Ames, an eloquent Massachusetts statesman, and the chief stream of the township was called Federal creek.

A good representative geological section of the more important strata was seen north of the village of Ames, on the land of Jason Rice. Here we obtain:

		FEET.	IN.
1.	Buff, honey-combed limestone	2	0
2.	Laminated sandstone	10	0
3.	Not seen	20	0
4.	Coal, 1 in. slate, 8 in. from bottom	4	0

		FEET.	IN.
5.	Under-clay	3	0
6.	Not seen	72	0
7.	Limestone, no fossils seen	2 to 3	0
8.	Not seen	63	0
9.	Fossiliferous limestone, (Ames limestone)	2	0
10.	Laminated sandstone with shale	6	0
11.	Shale	5	0
12.	Bed of Brown's run	...	...

See Sec. No. 8, Map VIII.

The coal in this section is the Federal creek coal, the equivalent of the Pomeroy seam. It has been mined on Mr. Rice's land for many years to supply a local demand. Some searches made by me several years since, in company with some of the citizens of the township, failed to discover this seam of coal in the central and south-western part of the township. It has apparently thinned out or been cut away by erosion soon after its original deposition, and its place taken by sandstones or shales. An unerring guide to the place of this coal is the well known Ames fossiliferous limestone, everywhere found in the lower part of the valleys, about one hundred and forty feet below the horizon of the Federal creek coal. This limestone has a very wide range and is one of the best guides the geologist has in Athens county. Wherever this limestone is seen, it is only necessary to measure up the hill sides a vertical distance of about 140 feet to reach the coal. But it is my opinion that in many places in Ames and in Canaan townships, the coal is wanting.

The valleys in Ames township are generally broad and productive and attractive for their beauty. In the highest hills there is considerable limestone above the Federal creek seam of coal. This limestone is more fully seen in Homer township, of Morgan county, which lies north of Ames.

BERNE TOWNSHIP.

This township lies east of Ames, and is drained by Federal creek and its tributaries. The township is generally quite hilly, but the upper part of the valley of Federal creek, and nearly all the valley of Sharp's fork, are wide and fertile. Where the erosion has been more confined to sandrocks, the valleys are relatively narrow. The Federal creek or Pomeroy seam of coal, is found generally throughout the township. This seam of coal in this region, has a parting of fire-clay near the middle, measuring about a foot in thickness.

At Elliot's, Sec. 29, in this township, the following geological section was obtained:

		FEET.	IN.
1.	Sandstone	10	0
2.	Not seen	10	0
3.	Buff limestone	1	0
4.	Not seen, except shale at bottom	25	0
5.	Coal, } Pomeroy seam	4	0
6.	Clay, } Pomeroy seam	1	0
7.	Coal, } Pomeroy seam	4	6

In passing over the ridge, in Sec. 23, from Federal Creek valley, to the head of Marietta run, the following strata were seen:

		FEET.	IN.
1.	Sandstone and conglomerate	15	0
2.	Not seen	112	0
3.	Limestone, with interstratified clay	15	0
4.	Not seen	39	0
5.	Buff limestone	1	0
6.	Interval not seen, estimated	35	0
7.	Coal, Federal creek or Pomeroy seam	8	0

See Sec. No. 10, Map 8.

In the above section, the upper coal seam was not exposed.

The limestone so abundant on Limestone run is, I suppose, the heavy deposit seen in the above section, the geological place of which is about 70 feet above the coal.

In Fraction 35, the Federal creek seam afforded the following measurements:

		FEET.	IN.
1.	Coal	4	6
2.	Clay	0	10
3.	Coal	3	6

What was formerly called the "big coal bank," in Fraction 1, was, at the time of our visit, fallen in, and no measurements could be made. There were visible two feet of ferruginous shale over the coal, and above this 10 feet of sandy shale. Here the coal is very thick.

In a Geological Report prepared for a special purpose, by Col. J. W. Foster, formerly connected with the first Geological Survey of Ohio, I find a section of the coal and accompanying strata at the "big bank," taken in 1865, before the bank had fallen in. It is as follows:

		FEET.	IN.
1.	Sandstone, thick bedded, and weathering well, forming the caps of the hills, and somewhat fissile near the base, probably	50	0
2.	Light colored shale with numerous coal plants	2	6
3.	Bituminous coal, jet black and highly lustrous	4	6
4.	Highly bituminous shale or rather laminæ of coal with shaly films	0	11
5.	Ash colored fire-clay	1	0
6.	Coal externally like No. 3	4	5
7.	Dark bituminous shale	...	...

Total thickness of coal, eight feet and eleven inches.

"The eleven inches of slaty coal would, if mixed with the other coal, serve a purpose for boiling salt and similar uses. If added to the eight feet eleven inches above reported, the total would be nine feet ten inches of coal. The position of this slaty coal in the seam is such that it can be excluded from the rest, where the better quality is needed for shipment."

In Fraction 7 the following measurements were made:

		FEET.	IN.
1.	Sandstone, not measured	—	—
2.	Shale	4	0
3.	Coal	3	0
4.	Coal, passing into slate	0	10
5.	Clay	1	0
6.	Coal	4	6
7.	Underclay	2	—

On Nice's run, a branch of Marietta run, the following measurements were made:

		FEET.	IN.
1.	Sandstone, not measured	—	—
2.	Shale	8	0
3.	Coal	3	10
4.	Bituminous shale or slaty coal	1	6
5.	Coal	0	5
6.	Clay	0	10
7.	Coal, 3 feet 6 inches seen, 5 reported	5?	0
8.	Under-clay, &c	4	0
9.	Limestone, hard and bluish	2 to 5	0

At Warren Wickham's, near the mouth of Marietta run, the Federal creek coal presents the following subdivisions:

		FEET.	IN.
1.	Sandstone, 8 feet seen	8	0
2.	Ferruginous shale	6	0
3.	Coal	3	3
4.	Slaty coal	0	8

		FEET.	IN.
5.	Coal	0	3
6.	Clay	1	0
7.	Coal	4	0

See No. 12, Map VIII.

Here the upper bench of coal is not uniformly as thick as in the above section; the upper surface is undulating, and a portion of the coal is replaced by the shale.

A little below the mouth of Marietta run, where the road passes over the ridge between Federal creek and Spruce run, there is seen by the roadside an interesting exhibition of limestone imbedded in the heavy sandrock. It appears originally to have been a pure calcareous mud, filling cavities or depressions in the sand. This limestone is from 60 to 70 feet above the Federal creek seam of coal, and in this horizon we generally find limestone, but I have not elsewhere seen it intermingled with sandrock.

The following geological section was taken a little above McCune's mill, just below the mouth of Marietta run:

		FEET.	IN.
1.	Limestone embedded in large masses in heavy sandstone	2	0
2.	Hard, white sandstone	20	0
3.	Shale	3	0
4.	Coarse sandstone	40	0
5.	Shale	6	0
6.	Coal	2	0
7.	Slaty coal	0	8
8.	Clay	1	0
9.	Coal	4	3
10.	Not seen	6	0
11.	Limestone	1	6

For this section, see Sec. No. 15, Map VIII.

Along the more immediate banks of Federal creek are places where the coal is replaced by sandrock and shales. This is seen near McCune's dam, where, at one point, the coal is very thick, and near by very thin. This is often the case in other seams of coal. The old coal marsh in which the coal-vegetation grew, when submerged, was in places assailed by strong currents which removed the accumulated vegetation and left in the channel ways of erosion sand, and sometimes mud. Those familiar with the great seam of Sunday creek, in Perry county, will recall a similar example of the substitution of sandstone in the place of the coal on the headwaters of the West fork of Sunday creek, where suddenly the coal from being 11 feet or more thick is reduced to almost nothing. Fortunately these disturbances are generally quite limited in extent.

Nearly all of the old openings into this fine seam of coal in Berne township have fallen in, and it was impossible to obtain satisfactory samples of the coal for analysis. Many analyses have been made of this coal by different chemists, but they are so different that they lead to the belief that the coal varies greatly in purity at different localities.

In 1854, Prof. Newberry analyzed three samples with the following results:

"No. 1. Taken from lower bench at Wickham's.
No. 2. " " the very top of upper bench at Nice's run.
No. 3. " " " upper bench on land of G. M. Woodbridge.

	No. 1.	No. 2.	No. 3.
Specific gravity	1.312	1.377	1.307
Fixed carbon	47.119	46.648	48.010
Bitumen	45.781	45.552	44.855
Ashes	7.100	7.800	7.135
Total	100.00	100.00	100.00

"No. 1. Hardness, medium; color, brilliant black, with a remarkable metallic lustre; breaking apparently into tabular masses, which are separated by lines of *mineral charcoal.* Sulphuret of iron contained in *small* quantity and disseminated in fine particles.

No. 2. Physical characters similar to No. 1, but less brilliant and lustrous; more dense, and contains much more sulphuret of iron.

No. 3. Physical characters same as No. 1."

In 1866, samples of coal upon Marietta run, obtained by Col. J. W. Foster, were analyzed by Dr. Blaney, of the Rush Medical College, Chicago, and by Dr. Mahla, of the Chicago Medical College. Dr. Blaney's analyses are as follows:

"No. 1. From upper bench.
No. 2. " lower bench.

	No. 1.	No. 2.
Hygrometric moisture	3.20	3.80
Volatile bituminous matter	36.80	39.68
Fixed carbon	54.61	53.80
Ash	5.39	2.72
Total	100.00	100.00

"The color of the ashes in both specimens being almost white, is satisfactory evidence that the coal contains an unusually small quantity of sulphur, which is for the

most part combined with iron as a bi-sulphide, the iron remaining in the ash as peroxide, communicating a red color to the ash." *

Dr. Mahla made eight analyses with the following results:

" Nos. 1, 2, 3 and 4, taken from the upper bench.
Nos. 5, 6, 7 and 8, " " " lower bench.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Moisture	2.61	....	2.32	....	5.38	....	2.60	....
Volatile substances	25.19	25.87	31.44	32.18	30.77	32.50	31.83	32.68
Carbon in coke	63.08	64.77	63.23	64.73	60.00	63.38	61.19	62.83
Ash	9.12	9.36	3.01	3.09	3.90	4.12	4.38	4.49
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

"They contain very little sulphur. The specific gravity of the upper seam is 1.32, and that of the lower 1.27. In undergoing combustion they produce no clinkers, and leave an ash of a light gray or almost white color. They coke well and compare favorably with Erie coal."

Prof. Wormley has examined two samples taken from only one point, where a recent opening had been made. No samples were taken from the localities which furnished samples for Prof. Newberry and the Chicago chemists, as most of these old openings had fallen in.

The following are Prof. Wormley's results:

No. 1, sample from lower bench.
No. 2, " " upper "

	No. 1.	No. 2.
Specific gravity	1.295	1.314
Moisture	3.00	2.40
Ash	5.40	8.50
Volatile combustible matter	35.00	35.60
Fixed carbon	56.60	53.50
Total	100.00	100.00
Sulphur	5.49	4.99
Sulphur left in coke	2.23	3.29
Percentage of sulphur in coke	3.58	5.30
Fixed gas per lb. in cub. ft	3.42	3.01
Ash	Gray.	Gray.
Coke	Compact.	Compact.

The large amount of sulphur shown by this analysis is, I think, exceptional, and the samples came from a location—such as are found in all

* Prof. Wormley has shown that this test of sulphur is often unsatisfactory.

coal seams and in almost every mine—where the sulphur happens to be excessive. The analyses are given, not because I think they fairly represent the coal, but because they show that much sulphur may be in a coal uncombined with iron in the form of a bi-sulphide. Iron, if in sufficient quantity in these samples to combine with all the sulphur, would necessarily redden the ash in combustion, but the ash in both analyses is gray.

Salt. There is every reason to believe that by boring wells in this township, ample supplies of brine may be obtained for the manufacture of salt. The coal being the continuation of the Pomeroy seam, it is reasonable to suppose that, by boring to about the same depth as at Pomeroy, strong and abundant brine may be obtained. A deep well, bored several years since for oil, not far from the mouth of Marietta run, reached strata containing brine. The strength of the brine was thought to be good, although it was not subjected, so far as I know, to any practical or scientific tests. I have no doubt whatever that the brine would possess all needed strength. Salt furnaces located along the outcrop of the coal would obtain fuel at the minimum rate. A short branch railroad to connect with the Marietta & Cincinnati R. R. might remedy the difficulty of transportation. A road extending up Sharp's fork of Federal creek into Morgan county, would serve for the shipment of coal, salt and oil.

ATHENS TOWNSHIP

Is drained by the Hocking river, by Margaret's creek, Sugar creek, and several other smaller tributaries of the Hocking. The valley of the Hocking is often wide and the soil is fertile. Some well defined terraces are seen at various points. The *South-eastern Lunatic Asylum* is located upon one of these terraces. The gravel of the terraces is drift gravel, brought down the Hocking from its headwaters at a time when the river stood 80 feet, or more, higher than at present. These terraces are generally dry and afford desirable building sites. The old mound-builders often built their mounds and other earth-works upon them. The most remarkable and interesting terrace in Athens township lies near the north line of the township, on the back road to Salina, in Dover township. This terrace, called the "Plains," is now entirely disconnected from the present river valley. It indicates, however, an old river course which has been filled up. On this terrace a large number of ancient mounds is still to be seen. It must be remembered that the valleys of southern Ohio were chiefly eroded, essentially as we now find them, before the era of the Drift. Generally they were eroded below the level of the present beds, for the streams now flow, not upon the rock, but are sepa-

rated, for the most part, from the rock-bed by alluvial materials. Where the streams have their heads within the limits of the Drift, drift sands and gravels have been brought down and constitute high banks along the streams. This is, however, true only of the Muskingum, Hocking and Scioto rivers, in the Second Geological District. Other valleys have been more or less filled with alluvial sands and clays, derived from the wash of the bordering hills or brought down by the tributaries. In such valleys we find a depth of forty or fifty feet, sometimes, indeed, almost a hundred, of soft materials. These materials show no traces of Drift origin, and the inference is inevitable that Drift agencies neither eroded the valleys nor contributed towards filling them.

The town of Athens rests upon the sandy shales interstratified between two fossiliferous limestones, which are between 80 and 90 feet apart. The upper limestone I have called the Ames limestone, from its location in Ames, in Athens county, where it has a fine characteristic development, and where its relations to the Pomeroy or Federal creek coal were first ascertained. The lower is found interstratified with shales in the roadside not far from the bridge over the Hocking, a little east of the Marietta and Cincinnati railroad station. This limestone has a wide range, and I have called it the Cambridge limestone, it being found in the hills near Cambridge, Guernsey county. The lower limestone is elsewhere found to be not far from 200 feet above the Nelsonville seam of coal. This is about the depth of a shaft sunk at Athens near the railroad station to this coal. The top of the shaft is perhaps 10 feet below the limestone. The shaft is now filled with water, and no opportunity was afforded for obtaining a detailed section of the strata passed through. It is reported that 67 feet of sand rock were found directly above the Nelsonville coal, and below the coal were 13 feet of clay and shale containing nodules of iron ore. Above the heavy sand rock, sandy shales were chiefly passed through, and a thin seam of coal. The exact place of this coal is not known, but it is probable that it is the Bayley's run seam, generally found about 100 feet above the Nelsonville seam.

The Nelsonville seam in the shaft was not found to be evenly bedded, and was thought to be too irregular and thin for profitable working. It is an important question whether this irregularity is merely local or has a wide extent. At several points I have found irregularities in the bedding of the Nelsonville seam of coal which were limited in extent. The most remarkable is on the west branch of Sunday creek, along the border between Monroe and Salt Lick townships, Perry county. Here in some places the sandrock has, in popular phrase, entirely "cut away" the coal, and in others left it very uneven and irregular in thickness. From a point where the coal is entirely gone to another down the branch

where it is eleven feet thick and evenly bedded, it is probably not more than a quarter of a mile. At the first point the sandrock is very heavy, while at the latter it is nearly all gone and its place taken by shales. A similar transition is seen in passing from the C. & H. V. railroad, below the mouth of Meeker run, in York township, where the sandrock comes down upon the coal and cuts it away to some extent, into the valley of Meeker run, where we find, on the land of John L. Gill, the seam of coal 8 feet thick with no sandrock whatever above it. In the mining developments at New Straitsville, Perry county, there is also found a belt, not wider than the width of an acre, in which the sandrock often displaces a part of the coal. Mr. Clarke, the Superintendent of the Straitsville Mining Company, thinks that the top of the seam, after the coal had become hard and perfect, was eroded, and in the channels of erosion sands were deposited. He reports finding fragments of the coal in the sand now hardened into sandrock. A similar case of erosion of a part of the coal is seen on Lost run, in Ward township, Hocking county. In this and in all the cases mentioned, the disturbance of the coal is local, and, with the exception of that on the west branch of the West fork of Sunday creek, of very limited extent. At Salina there is a heavy sandrock over the coal, but the coal retains everywhere, so far as I know, a good thickness. At the mouth of Pickett's run, about two miles north of Athens, the same seam was passed in boring an oil well, and reported to be of the usual thickness. At the old De Steiguer salt works, three miles west of Athens, the same seam was reported to be of the usual thickness, and found at a depth of 140 feet below the surface. I have not the records of the boring at the old salt well on Rock Riffle run, nor of the borings at the wells of Pruden & Bro., in Canaan township. Where the Nelsonville seam comes to the surface on Raccoon creek, at Mineral City and westward, it is overlain with a heavy sandrock and the coal is relatively thin.

These facts should all be carefully weighed by those pecuniarily interested in the Athens shaft. It might even be thought best to bore down carefully, at proper distances from the shaft, to ascertain the thickness of the coal and its relation to the sandrock. If the coal were found covered by considerable thickness of shale or slate, the presumption would be that the coal would prove of uniform thickness. The fact, that the coal was found 5½ feet thick in places, shows that this is the original and normal thickness, as the coal seam was first formed. The strong probability is that if the region of disturbance were passed by drifts cutting the line of horsebacks at right angles, this thickness of coal would be found as a uniform thing. The location of the shaft directly upon the railroad is so good, that the shaft should not be aban-

doned, unless the owners are convinced that the seam in a more uniform condition of thickness cannot be reached by drifts at a reasonable expense. Fortunately for the people of Athens, the Nelsonville mines are not far distant, and the C. & H. V. Railroad is completed. There is also a seam of coal in the hills, to be noticed hereafter, from which a local supply could be obtained.

A fine section of the rock-strata was obtained on Rock Riffle run, about a mile south-east of Athens. It is as follows:

		FEET.	IN.
1.	Coarse sandstone	5	0
2.	Laminated sandstone with false bedding	15	0
3.	Shale	12	0
4.	Limestone, Ames limestone, fossiliferous	2	0
5.	Shaly laminated sandstone	5	0
6.	Compact sandstone	5	0
7.	Shale	10	0
8.	Black bituminous shale	2	0
9.	Coal	0	1
10.	Shale	7	0
11.	Limestone, impure and irregularly bedded	2	6
12.	Clay and clay shale	20	0
13.	Laminated sandstone with false bedding	20	0
14.	Sandstone partly laminated	14	0
15.	Limestone, earthy, fossiliferous, Cambridge limestone	1	9
16.	Laminated sandstone and shale	20	0

For this section see Sec. 6, Map VIII.

The only coal in this section is but an inch thick, 22 feet below the upper or Ames limestone. The slate over this coal is highly bituminous. It was afterwards found that the coal worked near Albany is probably this seam thickened to 1 foot 6 inches.

There are in the hills two seams of coal above the one a little below the upper or Ames limestone. The first one above is the equivalent of the Pomeroy seam, and is about 140 feet above the Ames limestone. The other is about one hundred feet higher. There should be another about 25 feet above the Pomeroy seam; at least, such a seam is found on Long run, on the other side of the ridge. The true place of this latter seam would be directly under the heavy sandstone. A geological section was made on the land of Thomas Laughlin, Sec. 3, on the high ridge south of Rock Riffle run, as follows:

		FEET.	IN.
1.	Top of high hill	...	...
2.	Not seen	5	
3.	Laminated soft micaceous sandstone	10	

		FEET.	IN.
4.	Shale	9	0
5.	Sandrock	6	0
6.	Not seen	30	0
7.	Buff limestone	1	0
8.	Not seen	27	0
9.	Blossom of coal	...	...
10.	Not seen	4	0
11.	Limestone, not fossiliferous	1	6

This section is seen in Sec. 13, Map VIII.

There is an interval of nearly 220 feet between the coal of the last section and the Ames limestone, and in this interval is the Pomeroy coal. The hill behind Mr. Laughlin's house is, by barometer, 450 feet above the Hocking river at the mouth of Rock Riffle run. The soil near the top of the hill is rendered fertile by the lime of the upper limestone layers.

A section was taken by Mr. Gilbert, to obtain the position of the coal seam worked by Major Augustus Norton, Sec. 4, about a mile and a half east of Athens, which is as follows:

		FEET.	IN.
1.	Buff limestone	1	0
2.	Not seen	29	0
3.	Coal	3	0
4.	Clay	1	0
5.	Coal	2	0
6.	Clay and not seen	4	0
7.	Sandstone and sandy shale with heavy sandrock at the bottom	102	0
8.	Not seen	140	0
9.	Ames limestone	1	6

See Sec. No. 17, Map VIII.

Mr. Norton's coal seam is the same as that mined by Pruden & Bro., in Canaan township, and is the same as the upper coal on Big run. This seam has been traced beyond the Muskingum river, and is the Cumberland coal in Guernsey county, the upper or sandstone coal of Noble and Washington counties, the upper Barnesville and upper Bellair seam in Belmont county. This seam and the Pomeroy seam are both found to have a very wide range. The latter is the equivalent of the Wheeling seam, which is, according to the Pennsylvania geologists, the same as the famous Pittsburgh seam.

At the old De Steiguer salt works, three miles west of Athens, there is

a seam of coal from which the fuel was obtained for the boiling of the brine. The following section was taken, showing the measurement of the coal:

		FEET.	IN.
1.	Limestone, fossiliferous	2	0
2.	Sandstone	8	0
3.	Coal	3	0
4.	Slate	0	2
5.	Coal	1	8

If the report that the Nelsonville seam of coal was passed through in boring the salt well, at 140 feet below this coal, we may infer that it belongs to a horizon where we sometimes find coal, but generally a thin seam. There is sometimes a fossiliferous limestone a little above, but this is not always persistent.

On the land of John Winget, Lot 116, is found a seam of cannel coal 2 feet thick, overlain by 2 feet of black shale. About 30 feet below is a stratum of fossiliferous limestone, and 75 feet below this another. The quality of the coal is fair, but it probably contains too much bi-sulphide of iron to make the coal desirable for gas making.

CANAAN TOWNSHIP.

This township lies directly east of Athens, and is drained by the Hocking river, which divides the township into two nearly equal parts. The hills bordering the Hocking valley are high and steep, but where the limestone appears we find some excellent land.

The principal seam of coal seen in this township, is the upper seam, the place of which is about 100 feet above the Pomeroy seam. This seam is worked by Messrs. Pruden and Bro., for use in their salt works, in Sec. 33. Mr. Gilbert obtained the following measurements:

		FEET.	IN.
1.	Shale, not measured	...	...
2.	Coal	2	
3.	Slaty coal and slate	1	0
4.	Clay	1	0
5.	Coal	2	8
6.	Under-clay, seen	2	0

Sec. No. 14, Map VIII.

This is the same as the Norton coal in Athens township. The same seam has been opened on Sec. 28, by S. S. Boyles, and on Sec. 34, by S. H. Mansfield. It is reported to be of the usual thickness.

The place of the Pomeroy seam of coal is under the heavy sandrock, which is seen in the hills bordering the Hocking valley. The coal

itself was not seen at any point. In the hills east of Warren's station, the Pomeroy coal should appear in the railroad cuts, but we found no trace of it. Indeed the heavy sandrock so visible to the west, and so largely developed on Big run, is not found at all in the neighborhood of Pilcher tunnel, where we should look for the Pomeroy seam. A section taken from the top of the Pilcher tunnel hill, westward, to the bottom of the cut, about one-fourth of a mile east of Warren's station, shows the following strata:

		FEET.	IN.
1.	Red shale, seen	9	0
2.	Limestone and red shale	9	0
3.	Laminated sandstone	12	0
4.	Shale	20	0
5.	Fine-grained sandstone	6	0
6.	Yellow shale	10	0
7.	Red shale	10	0
8.	Limestone	2	0
9.	Sandstone	2	0
10.	Shale	0	6
11.	Limestone	4	0
12.	Sandy shale	12	0
13.	Fine-grained sandstone, mostly laminated	20	0
14.	Shale	6	0
15.	Limestone	15	0
16.	Sandstone	6	0
17.	Blue shale	4	0
18.	Yellow shale	20	0

Sec. No. 19, Map VIII.

Here are nearly 170 feet in vertical range of strata, and yet no trace of the Pomeroy seam of coal was found.

Not far from the west line of the township, in the high hills, at the head of Rock Riffle run, the blossom of a seam of coal was seen, the place of which is about 100 feet above the horizon of the Pomeroy seam. The latter seam is found in the same hills, but no good exposure was observed.

ROME TOWNSHIP.

This township lies south of Berne and east of Canaan. It is drained by the Hocking river and Federal creek. The valleys are fertile and the soil generally good. There is considerable limestone in the hills, as will be seen by reference to the Map of Sections. Some of the hills are very rugged, and where the heavy sandstone strata abound, there are ledges and bluffs.

The Federal creek coal, the equivalent of the Pomeroy seam, is foun on Federal creek north of the crossing of the Marietta & Cincinnati R. R. This seam gradually dips below the bed of the creek. In its southern and south-eastern extension the coal appears to be thinner than in Berne township. To the west, where the Marietta & Cincinnati R. R. crosses the horizon of this coal, it was nowhere to be seen. The area over which this important seam of coal will be found gone, is considerable, chiefly in Canaan and the southern part of Ames townships.

On Federal creek and Big run, the coal is everywhere overlain by a heavy sandrock, which reaches a maximum thickness of fifty or sixty feet. The Pomeroy coal at Pomeroy has a similar heavy sandrock over it, but this stratum is not entirely continuous between the two points; for, in Lodi township, in this county, we find about thirty feet of clay shales above the Pomeroy seam. On or near the top of these shales is a second seam of coal, and over this coal a heavy sandstone. The same is true as we go west from Federal creek, on the line of the Marietta & Cincinnati railroad, in the neighborhood of Pilcher tunnel; the sandrock is almost entirely gone, while further west, in Athens township, the sandrock re-appears in great thickness.

The Federal creek or Pomeroy coal is mined by Messrs. Skinner & Bro., in Sec. 18, Rome township. Here the coal is reached by a shaft 25 feet deep. Formerly the coal was worked by a drift-way, but the coal lies so near the level of Federal creek that the water sometimes interfered with the working of the mine. In this mine the portion of coal above the usual clay parting is not worked. This upper bench becomes irregular, and it is often entirely gone as we follow the seam from Berne township south into Rome. Where the shaft was sunk the upper coal was not seen, there being over the fire-clay parting only 6 inches of black slate. The coal at the bottom of the shaft was four feet thick. The shaft at Big Run station was filled with water at the time of my visit. It is reported that only the coal below the clay parting was mined, when mining operations were carried on at this point. It is also reported that oil wells, bored some little distance up Big run, did not pass through this seam at all. The sandrock was passed through, but the coal was not found under it. If this report is true, it is only another illustration of the not uncommon fact that a coal seam is often locally replaced by sandstones or shales. The quality of this lower seam of coal in Rome township is fair. It probably is not pure enough for gas-making or the blast furnace, but answers well for household uses and for the generation of steam.

Near Big Run station we find another seam of coal in the hill-side, 46

feet above the level of the railroad track. This coal shows the following sub-divisions:

	FEET.	IN.
1. Shale seen	3	0
2. Coal	2	6
3. Clay	2	0
4. Coal	1	3

On the same Section 12, on the land of Philip Totnan, Mr. Gilbert made the following measurements of the same seam of coal:

	FEET.	IN.
Shale, not measured	...	...
Coal	2	6
Clay	1	
Coal	2	0

The place of this coal is seen in No. 24, Map VIII.

A sample of this coal was analyzed by Prof. Wormley, with the following result:

Specific gravity	1.375
Water	3.00
Ash	13.00
Volatile combustible matter	29.60
Fixed carbon	54.40
Total	100.00
Sulphur	2.84
Sulphur left in coke	1.37
Percentage of sulphur in coke	2.02
Color of ash	Gray.
Character of coke	Compact.
Permanent gas per lb. in cubic ft	2.98

This seam of coal is of wide range, extending from Athens county to Belmont county, where it is probably the upper Barnesville seam, and the one at Bellair 85 to 90 feet above the Wheeling seam. In many places over this wide area it becomes thin, but it is often found of fine thickness and is largely used. In Meigs county it was not seen. It is a little remarkable that neither this seam nor the Federal creek or Pomeroy seam is found directly on the Marietta and Cincinnati Railroad, in the hills between Federal creek and Warren's station. Further west, however, in Canaan township, the upper seam is generally found.

A very thin seam of coal was found in the hills east of Big Run station,

about 105 feet above the last mentioned coal. At Cutler station, in Decatur township, Washington county, a very thin seam is found in a railroad cut 45 feet higher. A general section along the line of the railroad east of Big Run station to Cutler station, in Decatur township, Washington county, is seen in Sec. No. 18, on Map VIII., and also in Sec. No. 25, Map VIII., showing details of strata about 4 miles east of Big Run station, and also in Sec. No. 21, Map VIII., showing the details at Cutler station. These are all the seams of coal seen in the neighborhood. The two lower ones are of value and will come into use more and more.

Limestones. The lowest seam of limestone lies five or six feet below the Federal creek or Pomeroy seam of coal. It is seen on Marietta run, in Berne township, and is occasionally found under the Pomeroy coal in several other counties. In the hill west of the railroad bridge, across Federal creek, a section was made which revealed considerable limestone. The section taken at the bridge and on the adjacent hill, is as follows:

		FEET.	IN.
1.	Limestone, whitish	3	0
2.	Shale	18	0
3.	Limestone, buff and porous	10	0
4.	Not exposed	15	0
5.	Sandstone, quarried	6	0
6.	Not exposed	37	0
7.	White limestone	1	0
8.	Yellow shale	12	0
9.	White clay and limestone	1 to 3	0
10.	Red Shale	9	0
	Level of railroad track	...	...
11.	Heavy sandrock	50	0
12.	Coal, Pomeroy seam once mined by shaft	4	0

The heaviest body of limestone found in Athens county was seen in an abandoned cut about 1½ miles west of Big Run station. There are here 30 feet of it, the upper layers of whitish color and the lower buff when weathered. This is the same group seen on the hill adjacent to Federal creek bridge, but there in less development. It is very limited in its range, for it is not seen, at least only a foot of it, in its proper horizon east of Big Run station, where careful sections were made. The localization of the deposits of the non-fossiliferous limestones of our Coal Measures is a characteristic feature. This class of limestones was formed of what was originally calcareous mud, filling local depressions in comparative shallows. Forty-five feet below the large deposit is a thin stratum of one foot in thickness.

A general combined section of the strata exposed in the cuts and vicinity of the railroad from the Federal creek bridge toward New England, is given in Sec. No. 20, Map VIII. The upper tunnel in the section is the more eastern one. The limestone in this region is now largely used on the track of the railroad as ballast for the ties. Portions of it would burn to lime, while other portions are probably too earthy to make good lime. Portions might possibly serve a purpose for hydraulic lime. The limestone group last mentioned must not be confounded with another 15 feet thick, seen in a railroad cut a half mile east of Warren's station, in Canaan township. The latter is 160 feet lower in the geological series.

A limestone is seen near the level of the Hocking river near Savannah, but its place in the series was not obtained. This may be a local and independent deposit, or may be the equivalent of something found further north. As we pass south into Meigs county, all the limestones above the Pomeroy coal disappear.

Conglomerate. In the hills bordering Big run we find heavy ledges of very coarse sandrock often passing into conglomerate. The better defined conglomerate is found in two horizons, one about 200 feet above the Pomeroy coal, and the other about 40 feet higher.

LODI TOWNSHIP.

This township lies south of Canaan and east of Alexander. With the exception of a small area in the north-east corner, the drainage is by the branches of Shade river, a stream which empties into the Ohio river in Olive township, Meigs county. The township is generally hilly. Many of the streams have eroded their channels below the Pomeroy coal-seam, and this coal is generally accessible. About 25 feet above the Pomeroy seam is another, which has a local development in this and Alexander townships, but has not been noticed elsewhere. The following is a section obtained on the land of Philip Haning: Sec. 32:

		ft.	in.
1.	Heavy sandrock, seen	25	0
2.	Sandrock unevenly bedded, showing part of a trunk of a silicified tree in place	5	0
3.	Blue shale, with coal plants	5	0
4.	Coal, reported 18 inches thick	1	6
5.	Shales, with nodules of limestone	25	0
6.	Pomeroy coal	3	0
7.	Shale and clay	12	0

See Sec. No. 26, Map VIII.

The above section is of great interest as showing the position of one of the trunks of petrified wood. These trunks are very often found on the upper branches of Shade river, lying in the beds of the streams.

Great quantities, even tons, of specimens of silicified wood from Shade river, have been obtained to enrich cabinets in various parts of the country. No very minute investigation has as yet been made of the samples so far as I know. Mr. Leo Lesquereux is now engaged in the study of them, and it is believed that his results will be interesting and valuable. There are doubtless many different kinds of wood, and when specimens are properly prepared for microscopic investigation, the structural differences will be still more apparent. Mr. Lesquereux believes that the fragments of trunks are found in the shales between the two coals, as well as in the sandstone above the upper coal where I found them. From repeated visits to this region, I am led to believe that the trees, after drifting about and many of them partly rotting away, were buried in the sand, and while thus buried, were slowly changed into silex from silica derived, probably, from the sand of the sandrock. The portion of a trunk seen in place on the Haning farm, had more than half rotted away before it was silicified. It lies in the sandrock in a horizontal position, and the false bedding of the sandrock around it indicates the rolling of waves upon a sandy beach.

One of the most interesting of the Shade river petrifications is a peculiar disc, often three or four feet in diameter, composed of a mass of flattened rootlets, resembling somewhat those of *Stigmaria*. These rootlets radiate from a common centre, and evidently grew in a dense bunch around the Psaronius tree. The tree, however, is generally gone, either leaving a cavity in the centre of the disc, or a depression upon both the upper and under sides. Many years since, I found one of those discs, showing the remains of the central trunk. The tree had fallen and evidently pressed upon one side of the mass of rootlets, and had in that position partly rotted away before the whole had become silicified.

The Pomeroy seam of coal, generally reported to be four feet thick, is mined for neighborhood use in Sections 16, 17, 19, 25 and 32, and along the whole length of Long run, in this township.

On Long run we find the two seams of coal about 25 feet apart. These are seen in Sec. No. 27, Map VIII.

Below the lower, or Pomeroy seam, I observed 12 feet of shales, and below these at least 40 feet of sandrock. There is also a very heavy sandrock above the upper coal. Long run has for miles eroded its channel in the lower sandrock and the highway, taking the bed of the stream, passes through one of the most picturesque and romantic ravines to be found in the state. Generally the rock on either side is in vertical walls, from 20 to 40 feet high, and overhung with hemlocks. Ferns grow in great luxuriance and beauty in this damp and shady ravine. Occasion-

ally one sees in the bed of the stream, fragments of silicified trees, which have probably come from the disintegrating sandrock above the upper coal. Although I have examined carefully the rock walls of the stream, formed of the lower sandstone, I have never found any silicified wood in place in them.

ALEXANDER TOWNSHIP.

This township lies directly south of Athens. It is drained chiefly by Margaret's creek and its branches. On the eastern and south-eastern margin the water flows into Shade river. The valleys formed by Margaret's creek and its tributaries are generally wide and of great beauty, and some of the finest farms of the county are in this township. The breadth of these valleys is due to the soft shales which largely make up the strata in this neighborhood. Being easily eroded, the surface-waters during long ages have had comparatively easy work in wearing away the hills. There is not enough limestone in the hill-sides to give perpetual fertility to the soil without resort to artificial methods; but where there has been careful and intelligent husbandry the farms are very productive, affording the finest meadows and pastures.

The best guide to the geological formations in Alexander township is the fossiliferous limestone, the equivalent of the Ames limestone, which is well developed, and which is everywhere about 140 feet below the Pomeroy seam of coal. About 25 feet, by estimate, below this limestone is a seam of coal, which in some places has been mined for neighborhood use. This seam extends through Morgan, Muskingum and Guernsey counties. At Samuel Wines', Lot 4, section 32 and 33, the coal was found to be 1 foot 6 inches thick. Over it are 4 feet of sandy, bituminous shale, containing marine animal fossils, but not well preserved. Twenty feet above the black shale is a fossiliferous limestone, the Ames limestone. Below the coal 20 feet of drab clay shales were seen. (For the place of the Wines' coal, see Sec. 16, Map VIII.) Wherever the valleys are deep enough, another limestone about 85 feet below the one before mentioned should be found. This is seen frequently in Lee township, and also in Athens. It is this lower or Cambridge limestone which often changes into flint. Sometimes the lower portion of the seam is flint, while the upper is limestone. Much of the seam shows a combination of both, and is calcareo-silicious. Both the limestone and the flint contain fossils. The flint breaks out in rectangular blocks, and advantage is taken of this form in using the stone for doorsteps and similar uses. Dr. Hildreth, in the old *Geological Reports*, refers to this flint. It is not to be confounded with the Vinton county buhr or flint. It lies about 200 feet higher in

the geological series. The flint in Lee township is reported by Mr. John Brown, of Athens, to attain sometimes a thickness of 6 feet. Generally the lands of the township are too low to take in the Pomeroy seam of coal, which is about 140 feet above the Upper or Ames limestone.

On a high knob in Lot 4, Sec. 26, on land belonging to Col. Isaac Stanley, we find a blossom of the Pomeroy seam, and 27 feet above, another blossom of coal. These correspond to measurements made in Lodi township.

The whole section at this point is as follows:

		FEET.	IN.
1.	Sandrock, on top of knob	20	0
2.	Blossom of coal	...	...
3.	Shale, with nodular limestone	27	0
4.	Blossom of Pomeroy seam of coal	...	...
5.	Interval, not seen in detail, but mostly yellow shale	145	0
6.	Ames limestone, fossiliferous	2 to 3	0

See Sec. No. 22, Map VIII.

The knob is very high, and commands a wide prospect. Of course the highway runs over the top of it! The eastern dip brings this group of coals somewhat lower in the high hills which divide the waters of Margaret's creek from those of shade river. In these hills the sandrock, of which we saw only 20 feet on the high knob last mentioned, becomes very thick.

This sandrock is well seen on the home farm of Col. Stanley, Sec. 16. A blossom of coal was seen under this sandrock. This is, probably, the upper coal, and the Pomeroy seam should be found from 25 to 30 feet below. The guide to the Pomeroy coal in all this region must be the Ames limestone, which, over a very wide area, is found to be from 140 to 145 feet in vertical distance below that seam.

On the land of Henry Logan, in Sec. 10, the coal is opened and was found by measurement to be 3 feet 8 inches thick. It is overlain with slate. The coal appears to be of good quality. The place of this coal is seen in Sec. 23, Map VIII. It is regarded as the Pomeroy coal, which it certainly resembles in its physical properties. There were no exposures of any related strata, and it was impossible to decide the question with certainty, but I have no doubt that it is the Pomeroy seam. The coal evidently passes through the range of hills to the valleys of the tributaries of Shade river.

LEE TOWNSHIP.

This township lies west of Alexander and south of Waterloo. The western half of the township is drained by tributaries of Raccoon creek; the eastern and north-eastern by Margaret's creek, and the south-eastern

by Leading creek. These various divergent streams do not have their heads in a high central ridge, as might be first supposed, but rise in the central part of the township, where the land is not high and ridgy, but presents a broad, undulating surface, well adapted, in this respect, to agriculture. The general geological range of this region is in strata which extend from perhaps 50 feet above the Ames limestone down to 50 or 60 feet below the lower or flinty limestone. As the limestones are about 85 to 90 feet apart, this will give a vertical range of about 200 feet. Unfortunately, this range gives very little good coal. Near Albany there is a thin seam estimated to lie about 25 feet below the upper or Ames limestone. This seam, at a point where measured on the land of Mr. Wines, in Alexander township, just east of the township line, was found to be only 1 foot 6 in. thick. This seam is mined in a small way for neighborhood use. Much coal however is brought from Knox township in Vinton county, obtained from a seam which I regard as the equivalent of the Nelsonville seam. Another seam of coal, about 50 feet above the Nelsonville seam, is found in the bed of Rock Camp run in Sec. 19, Waterloo township, a little north of the north line of Lee township. But the coal is so low that I doubt whether that part of Rock Camp valley within Lee township is low enough to reach it. It might possibly be found in the low valleys of Doughty and Flint runs, in the extreme western edge of the township. In all these valleys it is probable that the Nelsonville or Mineral City seam of coal might be reached by shafts. I saw no hills in the eastern part of the township high enough to take the Pomeroy seam. That seam is seen on a very high knob about 4 miles north-east of Albany. It is over 400 feet in vertical distance above the Nelsonville seam in Knox township.

It is reported that nearly fifty years since, Mr. Brown, in digging a well not far from Albany, found, after passing through 40 feet of soil, clays, &c., a layer of buried vegetable matter composed of wood and black muck. It is probable that there might have been here, as we find in Barlow, Washington county, an ancient lake and that the wood and vegetable matter accumulated on its shore, or was buried by sediments beneath the water. There is no proof whatever that we have here the remains of a "Drift forest bed," the geological equivalent of that found by Prof. Orton in the Drift of Montgomery county. The regular Drift never reached as far to the south-east as this.

CARTHAGE TOWNSHIP.

This township lies directly south of Rome and east of Lodi. The principal stream by which it is drained is the East branch of Shade river. On the east and north are several small streams flowing into the

Hocking. The township is hilly, and the rock strata are largely sandstones and shales. In Fraction 18, there is found in the bed of a branch of Shade river a limestone, which Hon. E. H. Moore supposes to be the same as that found in the bank of the river near Savannah in Rome township. Probably the same limestone is to be seen in sections 19 and 25. In these sections, Mr. Ackley reports "a seam of coal from 2 to 3 feet thick under a heavy sandrock. Under the coal, from 30 to 50 feet, are to be found large nodules of iron ore, below which is a thick bed of limestone." In Fractions 18 and 30, there is a seam of coal which is mined for neighborhood use. The seam is reported to be 3 feet thick, one foot of which is cannel coal. Examinations have not yet been made to determine the exact place of this seam of coal in the stratigraphical series. It may be the equivalent of a thin seam which is found on the Marietta & Cincinnati railroad, near Cutler station, in Decatur township, Washington county. This seam is about 200 feet above the Pomeroy seam.

TROY TOWNSHIP.

This township lies in the extreme south-eastern corner of the county. It is the only township of the county which touches the Ohio river. It is chiefly drained by the Hocking river and its smaller affluents. This river flows somewhat diagonally through the township, giving to it ten or twelve miles of rich alluvial valley. Adding to this three or four miles of the immediate Ohio river valley, we find this township endowed with a very a large amount of very fertile land. This must be taken as a compensation for the great dearth of valuable minerals. This township lies in a geological range which seldom affords any valuable seams of coal or iron ore. Hereafter, examinations will be made in hope of finding something of economic value.

The Cumberland seam of coal, the place of which is about 100 feet above the Pomeroy seam, is doubtless below the bed of the Hocking river in this township. One hundred feet higher is another seam which has considerable range through the western part of Washington county. This seam ought to show itself in this township. There is another seam 135 feet still higher, which should appear in the Carthage hills. This latter seam is found in the eastern part of Meigs county. The two last mentioned seams are generally thin, and nowhere are mined except for local and neighborhood supply.

REGISTER OF ATHENS COUNTY.

MAP VIII.

No.		
1.	Geological Section	showing the stratigraphical position of Nelsonville coal in Sec. 4, Ward township, Hocking county.
2.	"	on land of Mr. Newton, Sec. 11, Trimble township.
3.	"	on land of James Rutter, Sec. 10, Trimble township.
4.	"	on land of L. Weethee, Mount Auburn, Sec. 18, Dover township.
5.	"	in Sec. 18, Dover township.
6.	"	"Rock Riffle run," Athens township.
7.	"	in Sec. 1, Waterloo township.
8.	"	on land of James Rice, Sec. 11, Ames township.
9.	"	on East branch Rock Camp run, Sec. 19, Waterloo township.
10.	"	from ridge in Sec. 23 down to Marietta run, Berne township.
11.	"	on land of W. C. Foster, Sec. 6, Knox township, Vinton county.
12.	"	at Warren Wickham's, mouth of Marietta run, Berne township.
13.	"	on land of Thomas Laughlin, on ridge south of "Rock Riffle run," Athens township.
14.	"	Pruden's coal bank, Canaan township.
15.	"	on Federal creek, a little below the mouth of Marietta run, Berne township.
16.	"	on land of Samuel Wines, Lot 4, Alexander township.
17.	"	including Maj. Augustus Norton's coal bank, 1½ miles east of Athens.
18.	"	on Big run, 3 miles east of Station, Rome township, and up to Cutler Station, Decatur, Washington county.
19.	"	from top of Pilcher Tunnel hill westward, Canaan township.
20.	"	from Federal creek railroad bridge to New England Station, Rome township.
21.	"	four miles east of Big Run Station.
22.	"	on land of Col. Isaac Stanley, Lot 4, Sec. 26, Alexander township.
23.	"	on land of Henry Logan, Sec. 10, Alexander township.
24.	"	on land of Philip Totnan, Sec. 12, Rome township.
25.	"	at Cutler Station, Decatur, Washington county.
26.	"	on land of Philip Haning, Sec. 32, Lodi township.
27.	"	on Long run, Lodi township.

CHAPTER XI.

REPORT ON MORGAN COUNTY.

This county is situated upon the Muskingum river, between the counties of Muskingum and Washington, and lies wholly within the Coal-Measures. The surface is drained by the Muskingum river and its tributaries, excepting a limited area in the south-west portion of the county lying upon the headwaters of Federal and Sunday creeks, branches of the Hocking river. The land is hilly, but the soil is generally excellent and well adapted to most forms of agriculture. As will be seen hereafter, the county is well supplied with limestone, which contributes largely to the fertility of the soil. The seams of coal are, the Pomeroy seam, found in very large and fine development in Homer and Marion townships; the Cumberland seam, which, although generally thin, has a wide range through the county; a seam 120 feet above the Cumberland, and another about 100 feet still higher. At one point a thin seam was found 73 feet below the Pomeroy seam. The seams of coal found directly upon the Muskingum river are, unfortunately, generally quite thin.

Should a railroad be built to the Perry county coal fields, a cheap supply of fuel could be obtained, and manufactures might be established largely upon the Muskingum river at Malta, McConnellsville and other points. Could the valley of Sharp's fork of Federal creek, in Homer and Marion townships, be reached by a railroad, an ample supply of coal could be obtained from that direction. For the blast furnace, the latter coal would not, probably, answer as well as the Perry county coal, but for most uses it will serve an excellent purpose.

The great want of the county is railroads. The production of salt might be almost indefinitely increased, with increased facilities for transportation of fuel to the furnaces and of the manufactured salt to the markets. With suitable transportation from Homer and Marion townships,

large quantities of salt might be profitably made, the Federal creek or Pomery seam of coal furnishing an unlimited supply of cheap fuel. A railroad reaching these townships would also stimulate a larger production of petroleum.

Salt is now one of the most important of the products of the county. By reference to the Map of grouped sections, it will be seen that the geological horizon of the Pomeroy seam of coal has a wide range in the county. At Pomeroy the best brine is found about 1,000 feet below this seam of coal in the sandstone strata of the Upper Waverly group. This is the lowest formation into which it will be necessary to bore the salt wells, and this well known saliferous group is accessible in nearly all parts of the county. Hence, the salt producing area is very large. But on Duck creek, in Washington and Noble counties, good brine is obtained in sandrocks interstratified with the Coal-Measures, and consequently nearer the surface; and it is highly probable that the same is true in Morgan county. The investigations of the geological and chemical questions involved in the existence and production of salt in the Second Geological District are reserved for a subsequent volume. There are, doubtless, large stores of petroleum beneath the surface in several townships. The more full discussion of the oil-bearing districts of the State is also reserved for another volume.

YORK TOWNSHIP.

This township lies in the extreme northwest corner of the county. Near the western line of the township, nearly west of Deavertown, we find, in the low valley of Black's fork of Moxahala creek, the upper New Lexington or Straitsville coal. The exposure at this point is as follows:

		FEET.	IN.
1.	Shale	10	0
2.	Slaty coal	0	4
3.	Clay	0	3
4.	Coal	1	4
5.	Slate	0	1
6.	Coal	2	6

The coal is mined at this point, and is of excellent quality, so far as seen. No opportunity was afforded for ascertaining whether the lower New Lexington coal, the place of which is from 25 to 30 feet below, exists here. It might easily be ascertained by boring. The place of the Hildreth calcareo-silicious stratum is about 160 feet above the upper New

Lexington coal. A section was taken in Sec. 29, near the centre of York township, as follows:

		FEET.	IN.
1.	Limestone	2 to 4	0
2.	Not exposed	12	0
3.	Sandstone, quarried	8	0
4.	Not exposed	62	0
5.	Conglomerate with fine quartz pebbles	10	0
6.	Limestone	3	0
7.	Not exposed	138	0
8.	Limestone fossiliferous, Ames limestone	1 to 5	0
9.	Not exposed	130	0
10.	Hildreth's calcareo-silicious rock	2 to 10	0

For this Section, see No. 1, Map IX.

The sandstone, No. 3, in this section, has considerable range, and is quarried at Triadelphia, in Deerfield township, where it is highly esteemed. The coal seams, which elsewhere lie above the upper New Lexington coal, have, as yet, never been found in this township. It is possible that some may hereafter be discovered, examination being made at their proper horizons. The Alexander seam of Muskingum county, is about 80 feet above the upper NewLexington seam. The Pomeroy seam is about 150 feet above the Ames fossiliferous limestone.

DEERFIELD TOWNSHIP.

The same barrenness of coal seen in York township appears to prevail in this township. The Ames limestone was seen, and the two deposits of limestone above it, given in the York township section, but no coals were found in the horizons where they are seen elsewhere. No good sections were taken in the township. The upper limestones are well developed, and serve a valuable purpose in fertilizing the soil.

UNION TOWNSHIP.

In section 2, in this township, and in section 16, the following combined geological section was obtained, the lower part made up from records of oil well borings:

		FEET.	IN.
1.	Sandstone	12	0
2.	Coal, Pomeroy seam	2	0
3.	Under-clay, not measured	...	...
4.	Not exposed	120	0
5.	Shale	25	0

		FEET.	IN.
6.	Fossiliferous limestone, Ames limestone	2	0
7.	Shale	4	0
8.	Sandstone	5	0
9.	Shale	15	0
10.	Coal	0	8
11.	Shale	14	0
12.	Limestone	1	8
13.	Soft sandstone, oil rock	11 to 15	0

Sec. No. 2, Map IX.

Several oil wells have been bored in the valley of Buck run, a branch of Wolf creek. The oil-bearing rock is reported to be reached at about the depth of 100 feet from the surface of the valley. When first bored the yield was considerable. When visited by Mr. Gilbert, only three wells were pumped by engines. The yield was reported from 3 to 5 barrels per day. Several are pumped by hand at intervals. The oil is here found in a rock about 40 feet higher than at the Joy farm, in Homer township. Hon. Mr. Stanton, of McConnelsville, reports the production of oil on Buck run, for 6 months, commencing January 1, 1871, at 1,086 barrels. In section 31, in Union township, a geological section was taken, as follows:

		FEET.	IN.
1.	Fossiliferous limestone, Ames limestone	2	0
2.	Laminated sandstone	25	0
3.	Bituminous shale	0	6
4.	Coal	0	6

This is in the valley of the east branch of Sunday creek. Many years since I visited the farm of Rev. J. P Weethee, in this valley, and found fine oil springs issuing from under a blue sand rock, about 50 feet below the Ames limestone. Wells bored for oil in this region, at that time, were not successful.

The following section was taken near Ringgold, in Sec. 21:

		FEET.	IN.
1.	Limestone	3	0
2.	Not exposed	45	0
3.	Coal, Pomeroy seam, reported thickness	3	0
4.	Not exposed	50	0
5.	Coarse sandstone	15	0
6.	Shale	8	0
7.	Coal	2	0
8.	Underclay	...	...

See Sec. No. 3, Map IX.

HOMER TOWNSHIP.

This township is in the south-west corner of the county, and is drained by the upper branches of Federal creek. The soil is rich, especially in the valleys.

The Pomeroy coal extends through the township, and is everywhere very thick and valuable. It may always be found about 140 feet above the Ames fossiliferous limestone.

The following section was taken on the land of J. Stinchcomb, Sec. 29:

			FEET.	IN.
1.	Buff limestone		1	0
2.	Not exposed		12	0
3.	Sandstone		6	0
4.	Clay shale, with coal plants		10	0
5.	Coal	Pomeroy seam	4	2
6.	Fire clay	Pomeroy seam	1	0
7.	Coal	Pomeroy seam	4	0
8.	Not exposed		143	0
9.	Ames limestone, fossiliferous		2	0

See Sec. No. 15, Map IX.

The strata above the coal were seen at Shaner's bank, and are not given in the map. At Shaner's the upper bench of coal measures 4 feet 2 inches.

At Mountville, Sec. 17, a similar section was made, excepting that the bench of coal above the fire clay parting was not seen.

In Sec. 34, on the land of Mr. Bishop, the following section was taken:

			FEET.	IN.
1.	Buff limestone		1	0
2.	Not exposed		27	0
3.	Coal	Pomeroy seam	3	0
4.	Clay, with coal plants	Pomeroy seam	1	0
5.	Coal	Pomeroy seam	4	1
6.	Not exposed		142	0
7.	Ames limestone, fossiliferous		2	6

A section was made on Lot 6, one mile north of Wrightsville, as follows:

		FEET.	IN.
1.	White limestone	6	0
2.	Not exposed	27	0
3.	Buff limestone	2	0
4.	Not exposed	19	0
5.	Coarse sandstone and conglomerate	15	0
6.	Not exposed	45	0
7.	Limestone, weathered buff	2	0

		Feet.	In.
8.	Not seen	20	0
9.	Shale	10	0
10.	Coal } Pomeroy seam	4	2
11.	Clay } Pomeroy seam	1	0
12.	Coal } Pomeroy seam	3	10

See Sec. No. 20, Map IX.

The following section was taken on the Joy farm, Sec. 2:

		Feet.	In.
1.	Sandstone	15	0
2.	Coal, (Pomeroy coal) reported thickness	3	6
3.	Not exposed	147	0
4.	Ames limestone, fossiliferous	1	0

The following is a record of strata passed through in an oil well bored on the same farm:

		Feet.	In.
1.	Ames limestone, fossiliferous	1	0
2.	Interval to top of well	8	0
	Top of well	—	—
3.	Red shales and sandstone	48	0
4.	Blue shale	4	0
5.	Laminated blue sandstone	10	0
6.	Hard sandstone	9	0
7.	Sandstone and shale	6	0
8.	Hard sandstone, oil rock	13	0
9.	Shale	9	0

The following is the record of another well bored on the same farm:

		Feet.	In.
1.	Ames limestone, fossiliferous	1	0
2.	Interval to top of well	9	0
	Top of well.		
3.	Soil	6	0
4.	Blue clay shale	50	0
5.	Blue sandstone	24	0
6.	Black Shale	8	0
7.	Sandstone, oil rock	4	0

The oil rock, so called, on this farm, is reported to be a coarse sandstone almost a conglomerate. The fissures containing the oil are found in this rock, but in the earlier days of oil operations, oil was sometimes found in strata nearer the surface. A seam of limestone one foot thick, is reported as sometimes found 69 feet below the Ames limestone. The quantity of oil produced in the region of the Joy farm, in 1870, was reported at between 5,000 and 6,000 bbls. The most productive well is said to produce 10 bbls. a day. Several others range from 1 to 3 bbls. a day.

In Sec. 1, in this township, the following section was taken:

		FEET.	IN.
1.	Limestone with white clay interstratified	8	0
2.	Not exposed	100	0
3.	Laminated sandstone	10	0
4.	Shale	15	0
5.	Limestone	0	6
6.	Shale with nodules of limestone	20	0
7.	Sandstone	2	0
8.	Buff limestone, honey-combed	4	0
9.	Blossom of coal	...	...
10.	Dark clay shale	3	0
11.	Not exposed	24	0
12.	Buff limestone, honey-combed	1	0
13.	Not exposed	12	0
14.	Sandstone	15	0
15.	Coal, seen, } Pomeroy seam	2	0
16.	Clay, } Pomeroy seam	1	0
17.	Coal, } Pomeroy seam	4	0

The blossom of coal 55 feet above the Pomeroy seam, is perhaps only a stain of bituminous slate or shale. No valuable seam of coal has ever been found in that horizon.

MARION TOWNSHIP.

Marion township lies directly east of Homer township. The Pomeroy seam of coal is well developed in the south-western corner.

A section was taken in Sec. 25, showing the following strata:

		FEET.	IN.
1.	Sandstone	20	0
2.	Not exposed	110	0
3.	Limestone	2	0
4.	Not seen	17	0
5.	Buff limestone	1	0
6.	Not exposed	18	0
7.	Blossom of coal	...	...
8.	Not exposed	18	0
9.	Buff and white limestone	2	0
10.	Not exposed	62	0
11.	Sandstone	10	0
12.	Pomeroy coal, not measured	...	...

The following section was taken in Sec. 26, in this township:

		FEET.	IN.
1.	Limestone with interstratified clay	30	0
2.	Shale	10	0
3.	Limestone	2	0
4.	Not exposed	57	0
5.	Sandstone and conglomerate	10	0
6.	Laminated sandstone	10	0
7.	Not exposed	55	0
8.	Shale	5	0
9.	Coal, } Pomeroy seam	4	0
10.	Clay, } Pomeroy seam	1	0
11.	Coal, } Pomeroy seam	4	0

A section was taken in Sec. 19, as follows:

		FEET.	IN.
1.	Limestone	4	0
2.	Mostly shale	50	0
3.	Sandstone and conglomerate	12	0
4.	Laminated sandstone	35	0
5.	Sandstone	10	0
6.	Shale, mostly	35	0
7.	Coal, lower part slaty, } Pomeroy seam	4	0
8.	Clay, } Pomeroy seam	1	0
9.	Coal, } Pomeroy seam	4	5
10.	Under clay	3	0

See Sec. No. 21, Map IX.

In this section, the upper coal was not seen.

The Pomeroy seam of coal is mined at many points in the southern part of this township. At one place, it measured 8½ feet of coal, exclusive of the clay parting. Penn township is supplied from this region. The principal banks are those of Messrs. Leak, Elliott & Edgerton. As a general rule, the upper layer of coal is not worked. The quality is not regarded as quite equal to the lower bench, and there is enough of the lower to meet easily all present wants. The coal in all this region serves an admirable purpose for household use, and for the generation of steam. It has never been applied to the purposes of iron and gas making. For these, there is in it, perhaps, too much sulphur. At no point has the upper coal seam, the one about 100 feet above the Pomeroy seam been worked. This upper coal is an important seam in other parts of this county and in other counties.

A section was taken partly in Sec. 2, in this township, on the land of J. B. Metzcar, and partly in Wesley township, in Washington county, as follows:

		FEET.	IN.
1.	Soft sandstone	20	0
2.	Not exposed	30	0
3.	Shale	10	0
4.	Cannel coal	0	2
5.	Clay	0	4
6.	Coal, with 1 in. parting	2	8
7.	Under clay, not measured	...	...
8.	Not exposed	54	0
9.	Blossom of coal	...	...
10.	Not exposed	60	0
11.	Limestone, white and buff	23	0
12.	Not exposed	6	0
13.	Sandstone	1	0
14.	Shale	6	0
15.	Coal	0	11
16.	Coal, slaty	0	4
17.	Coal	2	8
18.	Under-clay	2	0

See Sec. No. 22, Map IX.

Both of the coal seams in this section have been mined, the upper by Mr. Metzcar, by stripping. Several banks have been opened in the lower seam, and a supply obtained for neighborhood use. The lower seam is the one about 100 feet above the Pomeroy seam. It is the Cumberland seam.

PENN TOWNSHIP.

No valuable deposits of coal could be found in this township. Traces of the seam about 150 feet above the Cumberland seam, or about 250 feet above the Pomeroy seam, were observed, but at no point has the coal been found of workable thickness, so far as could be learned. The valley of Wolf creek is, probably, low enough to expose the Cumberland seam, but so far as we could learn, the coal had nowhere been opened This seam has a very slight development in Morgan county, west of the Muskingum river. Penn township is chiefly supplied with coal from the Pomeroy seam, in Marion township.

MALTA TOWNSHIP.

This township lies directly upon the Muskingum river. Like Penn township, it is unusually destitute of coal. A section was taken on Oil Spring Run in Sec. 32, as follows:

		FEET.	IN.
1.	Laminated sandstone	10	0
2.	Shale	10	0
3.	Limestone, Ames limestone, fossiliferous	1	0
4.	Shale	20	0
5.	Sandstone	12	0
6.	Not exposed	10	0
7.	Sandstone	30	0
8.	Shale	10	0
9.	Sandstone	15	0
10.	Shale	20	0
11.	Mostly laminated sandstone	15	0
12.	"Calcareo-silicious rock" (Hildreth's)	7	0
13.	Bituminous shale	10	0

See Sec. No. 5, Map IX.

No coal was found in this section. In Muskingum county, east of the Muskingum river, two seams of coal are found in this vertical space, although never of much thickness, perhaps not more than $2\frac{1}{2}$ feet thick. The proximate position of the so called "calcareo-silicious rock" of Dr. Hildreth is 150 feet above the Upper New Lexington or Straitsville seam of coal. This stratum in this region is not to be confounded with the different flint or buhr strata found in other counties. It is a stratum of comparatively local development. Dr. Hildreth, in the 1st *Geological Report*, (1838,) gives the following accurate and valuable account of this "calcareo-silicious" stratum :

"We find it lying high in the hills, and especially in Brush Creek township, near the south-west corner of Muskingum county. Here it assumes a yellowish color and softer texture, resembling a fine-grained, buff-colored limestone. It contains the usual fossils, of which terebratulæ are the most abundant. A short distance south, near the north line of York township, in Morgan county, it is seen in place, lying in regular successive strata, and forming a bed of 8 or 9 feet in thickness. From this place, which is about 2 miles north ot Deavertown, it can be traced down the waters of Island run and Oil run to the Muskingum river, and to a point two miles above McConnelsville, where it lies on a level of the surface of the water during its low stages. At McConnelsville this rock is passed in boring for salt water at a depth of 110 feet below the bed of the river, and is found to be a valuable and certain guide to all the borings below this point. The lower or main salt-rock is reached at the depth of about 650 feet below the calcareo-silicious rock, with little variation for the distance of 10 or 12 miles below, or as far as any wells have been sunk; which is proof that the intermediate strata vary but little in their aggregate, if they do in their individual thickness. The dip of the strata in this vicinity is greater than I have noticed at any other place. At Campbell's mills, two miles from the Muskingum river, on Island run, this rock forms the bed of the stream, in a smooth, regular floor, over

which the water falls 15 feet, having cut away the dark bituminous shale which lies under the rock five or six feet in depth. * * * * From Deavertown to Campbell's, a distance of about 8 miles, there is a dip of 250 feet, and to the river about 50 feet more."

Petroleum has been found in sections 21, 32 and 5. There were oil springs in this region, which gave the name to the run. The oil-bearing strata of Buck run, in Union township, and on Sharp's fork, in Homer township, are a little higher in the geological series than the rocks penetrated by wells bored in the valley of Oil Spring run. It is possible, however, that the original springs in the latter locality may have derived their oil from nearly the same horizon. Salt is made in Malta township, but the discussion of the salt wells, the salt-bearing rocks and the quality and strength of the brines, is reserved for another report.

On Wolf creek, 2 or 3 miles south of Malta, oil wells have been bored, and some of the wells have yielded a little oil.

BLOOM TOWNSHIP.

This township lies directly north of Malta and Morgan townships. A section was taken in Sec. 1, on the land of V. Sevall, as follows:

			FEET.	IN.
1.	Limestone		2	0
2.	Shale		4	0
3.	Limestone		2	0
4.	Shale		2	0
5.	Limestone		3	0
6.	Shale		10	0
7.	Limestone		2	0
8.	Not exposed		48	0
9.	Shale		2	0
10.	Coal,	Cumberland seam	0	6
11.	Slate,		0	1
12.	Coal,		1	4
13.	Slate,		0	1
14.	Coal,		2	0

See Sec. No. 8, Map IX.

The coal in this section is the Cumberland seam or the one about 100 feet above the Pomeroy seam. It is generally from 3½ to 4 feet in thickness, and is the only coal mined in the township.

A section was taken on Mann's fork of Meigs creek, Sec. 24, as follows:

		FEET.	IN.
1.	Limestone	1	0
2.	Shale	8	0
3.	Limestone	2	0
4.	Clay and shale	4	0
5.	Limestone	2	0
6.	Not exposed	92	0
7.	Limestone	2	0
8.	Not exposed	54	0
9.	Blossom of coal, Cumberland seam	...	...
10.	Not exposed	5	0
11.	Limestone	3	0
12.	Not exposed	145	0
13.	Laminated sandstone	18	0
14.	Shale	20	0
15.	Laminated sandstone	20	0
16.	Shale	27	0
17.	Limestone, Ames limestone, fossiliferous	1	6
18.	Bed of stream.		

See Sec. No. 6, Map IX.

The place of the Pomeroy seam of coal is about 140 feet above the Ames limestone. There were no exposures of the strata in that range where the above section was taken. The Pomeroy seam, so fine in Homer and Marion townships, has a poor development in this part of the county, and is often entirely wanting.

On the land of Mr. Townsend, Sec. 26, the following section was taken:

		FEET.	IN.
1.	Limestone	2	0
2.	Shale	8	0
3.	Limestone	1	0
4.	Not exposed	50	0
5.	Coal, Cumberland seam, not seen in detail, reported	3	6
6.	Clay	3	0
7.	Limestone	2	6

See Sec. No. 4, Map IX.

The coal has a shale roof, which often gives trouble in mining from its weakness.

Another section taken in Sec. 26, reveals the coal seam more distinctly:

		FEET.	IN.
1.	Limestone	3	0
2.	Not exposed	54	0
3.	Black slate	0	6

		FEET.	IN.
Coal,	Cumberland seam	1	9
5. Slate parting,	Cumberland seam	0	1
6. Coal,	Cumberland seam	2	0
7. Clay		3	0
8. Limestone, nodular		2	0

On the east bank of the Muskingum river, towards the south line of this township, is found a somewhat remarkable rock called the "Devil's Tea Table." It resembles somewhat an inverted pyramid. The height was estimated to be 25 feet. It, is on the summit of a ridge, and is simply the remnant, or outlier, of a sandstone stratum resting upon shales. The shales have been disintegrated and largely removed, as also has the lower and softer portion of the sandrock. This work of disintegration is now going on, and probably before many years the narrow base of the pyramid will give way, and the huge rock will go thundering down the hill on one or other side of the narrow ridge. Many large masses of the same sandrock have been undermined and fallen, and lie upon the sides and at the base of the hill. No earthquakes or convulsions of nature are needed to explain these facts.

MORGAN TOWNSHIP.

This is a small narrow township lying along the east bank of the Muskingum river. It contains McConnelsville, the county town.

Coal of the Cumberland seam has been dug about a mile north of McConnelsville, but at the time visited no measurements could be made. From this place considerable coal has been dug for the supply of McConnelsville. The coal was reported to be from 20 to 24 inches thick. The supply of coal for McConnelsville is obtained in part from the Blue Rock mines in Muskingum county. Edwin Sherwood's salt-works have been supplied from coal mined near the works. The works are on the east side of the river, four miles below McConnelsville.

A section of the strata was taken in Sec. 13, about half a mile southeast of McConnelsville:

	FEET.	IN.
1. Limestone	1	0
2. Not exposed	9	0
3. Limestone	1	0
4. Not exposed	46	0
5. Limestone	2	0
6. Not exposed	9	0
7. Limestone	1	0
8. Shale	9	0
9. Limestone	0	8

		FEET.	IN.
10.	Shale	19	0
11.	Sandstone, with some shale	18	0
12.	Bituminous shale and slate, probably the horizon of the Cumberland coal	13	0
13.	Laminated sandstone	30	0
14.	Limestone	2	0
15.	Shale	18	0
16.	Siderite iron ore	0	6
17.	Hard clay	2	0
18.	Sandstone, laminated in places	24	0
19.	Shale	10	0
20.	Sandstones and shales	50	0

See Sec. No. 12, Map IX.

BRISTOL TOWNSHIP.

Bristol township lies directly east of Bloom.

In Sec. 7, near Airington, the following section was taken:

		FEET.	IN.
1.	Limestone	3	0
2.	Sandstone	15	0
3.	Not exposed	25	0
4.	Blossom of coal	...	...
5.	Not exposed	99	0
6.	Laminated sandstone	15	0
7.	Shale	6	0
8.	Coal, Cumberland seam, only 2 feet seen	...	...
9.	Clay	3	0
10.	Limestone	2	0

See Sec. No. 7, Map IX.

The Cumberland coal seam was not fully seen. It is generally from 3 to 4 feet in thickness in this region. The blossom of coal 120 feet above the Cumberland seam is found in High Hill, in Meigs township, in this county. It is doubtless the same as the seam in the railroad tunnel at Barnesville, Belmont county.

In Sec. 28, in this township, not far from Bristol, were found the following strata:

		FEET.	IN.
1.	Limestone	2	6
2.	Not exposed	8	0
3.	Limestone	2	0
4.	Not exposed	9	0
5.	Limestone	1	6
6.	Not exposed	33	0
7.	Fine-grained sandstone, quarried	15	0
6.	Shale	6	0

		FEET.	IN.
7.	Coal, Cumberland seam	3	8
8.	Clay	3	0
9.	Limestone	3	0
10.	Shale	5	0
11.	Limestone	1	0
12.	Shale	20	0

See Sec. No. 9, Map IX.

The Cumberland coal is mined in this neighborhood. The following section was taken in Sec. 36:

		FEET.	IN.
1.	Shale	6	0
2.	Coal, } Cumberland seam	1	2
3.	Black slate, } Cumberland seam	0	6
3.	Coal, } Cumberland seam	2	0
4.	Clay	2	0
5.	Nodular limestone	1	0
6.	Shale	8	0
7.	Limestone	2	0

Bed of Bear run.

No coal is worked in this township, except the Cumberland seam. A blossom of another seam is sometimes seen 120 feet above, but it has nowhere been opened. It is doubtless quite thin.

MEIGSVILLE TOWNSHIP.

This township lies east of Morgan. The western half of the township is very high, occupying the high ridge between the waters of Muskingum river and Meigs creek. No sections were taken in this part of the township. A section was taken in Sec. 13, near the eastern side of the township, which reveals the following strata:

		FEET.	IN.
1.	Limestone	6	0
2.	Shale	8	0
3.	Limestone	4	0
4.	Not exposed	50	0
5.	Shale	4	0
6.	Coal, Cumberland seam	$3\frac{1}{2}$ to 4	0
7.	Clay	3	0
8.	Sandy limestone	2	0
9.	Mostly laminated sandstone	40	0
10.	Limestone	2	0

See Sec. No. 11, Map IX.

The Cumberland seam of coal is mined in this neighborhood, and supplies the local demand. No exposures were found high enough to reveal the seam of coal 120 feet above the Cumberland seam.

WINDSOR TOWNSHIP.

This township lies directly south of Meigsville township. In it the Muskingum river makes its most remarkable bend, flowing toward all points of the compass, excepting due west.

In Lot 1034, near Hooksville, a section was taken:

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Clay and shale	5	0
3.	Hard, laminated sandstone	3	0
4.	Not exposed	30	0
5.	Sandstone	8	0
6.	Shale and clay	9	0
7.	Limestone	1	0
8.	Laminated sandstone, not seen	15	0
9.	Limestone, whitish	6	0
10.	Shale	6	0
11.	Whitish limestone	8	0
12.	Shale	8	0
13.	Limestone, blue	2	6
14.	Shale	1	6
15.	Limestone	1	2
16.	Shale	16	0
17.	Coal, Cumberland seam	2	9
18.	Under clay	3	0
19.	Limestone	5	0
20.	Shale	5	0
21.	Limestone	5	0
22.	Shale	12	0
23.	Limestone	1	0
24.	Shale	5	0
25.	Laminated sandstone	8	0
26.	Shale	9	0
27.	Limestone	8	0
28.	Shale	20	0
29.	Heavy sandstone, quarried	20	0
30.	Interval to low water of Muskingum	26	0

See Sec. No. 16, Map IX.

The Cumberland seam of coal is here mined by J. Henry. The upper coal has never been opened. The sandstone, No. 29, in the above section, is quarried and worked into caps and sills, and has a fine reputation. The section reveals an unusual amount of limestone.

Another section was taken on Carter's run, which empties into the Muskingum about two miles below the village of Windsor, as follows:

		FEET.	IN.
1.	Limestone, white above, buff below	9	0
2.	Mostly shale	21	0
3.	Coal, Cumberland seam, reported	1	0
4.	Not seen	16	0
5.	Limestone, partly buff	6	0
6.	Clay shale	6	0
7.	Interval to water of Muskingum	63	0

See Sec. No. 17, Map IX.

Near Roxbury, four miles below Windsor village, a section was taken:

		FEET.	IN.
1.	Sandstone	20	0
2.	Shale	0	6
3.	Coal	1½ to 2	0
4.	Not exposed	75	0
5.	Sandstone	10	0
6.	Limestone, partly buff	9	0
7.	Not exposed	41	0
8.	Buff limestone	3	0
9.	Interval to water of Muskingum	58	0

See Sec. No. 18, Map IX.

The place of the Cumberland coal is in the space not exposed, marked No. 7, in the above section.

On Lot No. 64, in this township, on Olney's run, the following section was taken:

		FEET.	IN.
1.	Sandstone	15	0
2.	Not exposed	20	0
3.	Limestone	12	0
4.	Shale	9	0
5.	Limestone	6	0
6.	Shale	27	0
7.	Coal, very slaty	2	0
8.	Not seen	3	0
9.	Limestone	8	0
10.	Not exposed	16	0
11.	Laminated sandstone	8	0
12.	Limestone	2	0
13.	Shale	8	0
14.	Limestone	2	0
15.	Hard, laminated sandstone	40	0
16.	Shale	9	0
17.	Coal	1	0
18.	Under clay	1	0

See Sec. No. 19, Map IX.

The limestones in this township are very abundant. Some of the layers are partly magnesian, and careful search might reveal layers of valuable cement limestone. By selecting the stone, very fine white lime is made in this township.

The following section was taken one mile west of Windsor:

		FEET.	IN.
1.	Limestone, good quality	1	6
2.	Hard, magnesian limestone	1	6
3.	Limestone, upper 8 inches of good quality	2	2
4.	Magnesian limestone, white	0	10
5.	Limestone, good quality	0	6
6.	Magnesian limestone, white	1	0
7.	Limestone, good quality	1	0
8.	Magnesian limestone, weathered white	1	6
9.	Clay	0	8
10.	Limestone, upper 1 foot 6 inches good	2	0
11.	Magnesian limestone	1	3
12.	Shale, chiefly	10	0
13.	Buff limestone	2	0
14.	Shale	20	0

See Sec. No. 14, Map IX.

CENTRE TOWNSHIP.

This township lies in the southeast corner of the county, and directly east of Meigsville township. The township is drained by Olive Green creek. The hills are high and contain several layers of limestone. The principal development of coal is in the valley of Olive Green creek, in the southeastern part of the township. A geological section was taken in section 29, which showed the following strata:

		FEET.	IN.
1.	Limestone	4	0
2.	Not exposed	30	0
3.	Limestone	3	0
4.	Shale	18	0
5.	Coal, reported from 1 foot to	3	0

This coal has been worked to a very limited extent.

At Keith's mill, in the edge of Jackson township, Noble county, the seam of coal is $3\frac{1}{2}$ feet thick, and is mined for local use.

In Sec. 5, in Centre township, the following section was taken.

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Not exposed	154	0
3.	Limestone	4	0
4.	Shale	8	0
5.	Limestone	3	0

		FEET.	IN.
6.	Not exposed	30	0
7.	Limestone	1	0
8.	Shale	20	0
9.	Coal, } Cumberland seam	2	0
10.	Black slate, } Cumberland seam	1	0
11.	Coal, } Cumberland seam	1	0
12.	Clay	3	0
13.	Limestone	1	0
14.	Shale	8	0
15.	Limestone	2	0

See Sec. No. 13, Map IX.

The upper coal has never been opened, so far as could be learned. A seam of coal, near this geological level, is found in Monroe county and elsewhere, but it is nowhere considered to be of much value. The lower coal in this section is considerably used.

MANCHESTER TOWNSHIP.

This township lies in the extreme northeastern corner of the county. It is drained by the waters of Meigs and Olive Green creeks.

In the southeastern part of this township little coal has been dug, according to the reports. Coal is obtained from banks on Sec. 5, Centre township.

At Seeleyville, in Sec. 17, Manchester township, the following section was taken:

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Not exposed	5	0
3.	Laminated sandstone	20	0
4.	Not exposed	136	0
5.	Bluish limestone	3	0
6.	Not exposed	8	0
7.	Limestone	2	0
8.	Not exposed	49	0
9.	Coal, Cumberland seam	3	6
10.	Clay	3	0
11.	Nodular limestone	2	0
12.	Shale	6	0
13.	Limestone	1	0
14.	Blue sandy shale	15	0

See Sec. No. 10, Map IX.

The Cumberland coal is found in all this region and is mined in a small way at many points. The upper seam of coal has never been explored so far as ascertained.

REGISTER OF SECTIONS, MORGAN COUNTY.

MAP IX.

No.		
1.	Geological Section	in Sec. 29, York township.
2.	"	combined section in Sec. 2 and 16, Union township.
3.	"	near Ringgold, in Sec. 21, Union township.
4.	"	on land of Mr. Townsend, Sec. 26, Bloom township.
5.	"	on Oil Spring run, Sec. 32, Malta township.
6.	"	on Mann's fork of Meigs creek, Sec. 24, Bloom township.
7.	"	near Airington, Sec. 7, Bristol township.
8.	"	In Sec. 1, Bloom township.
9.	"	not far from Bristol, in Sec. 28, Bristol township.
10.	"	at Seeleyville, Sec. 17, Manchester township.
11.	"	in Sec. 13, Meigsville township.
12.	"	½ mile south-east of McConnelsville, Sec. 13, Morgan township.
13.	"	in Sec. 5, Centre township.
14.	"	one mile west of Windsor, Windsor township.
15.	"	on Sec. 29, Homer township.
16.	"	on Lot 1,034, Windsor township.
17.	"	on Carter's run, which empties into Muskingum, 2 miles below Windsor, Windsor township.
18.	"	near Roxbury, 4 miles below Windsor, Windsor township.
19.	"	on Lot 64, Olney's run, Windsor township.
20.	"	on Lot 6, a mile north of Wrightsville, Homer township.

CHAPTER XII.

REPORT ON MUSKINGUM COUNTY.

Only that part of the county which lies south of the Central Ohio railroad, belongs to the *Second Geological District.*

In many respects, this county is one of the most interesting in the District to the geologist. It presents a greater vertical range of strata than any other county. As we descend the valley of the Licking river, from Licking county, we find the Waverly sandstone group dipping but slightly to the south east, probably not more than 10 or 12 feet per mile, and as a consequence of this slight dip, we find the upper member of the group, which overlies the Waverly conglomerate seen at Black Hand, extending to the neighborhood of Pleasant Valley, before it passes beneath the surface. Upon the Logan or Upper Waverly, rest the proper Coal-measures, which from that point extend to the eastern line of the county and beyond. By careful measurements, we find as we climb higher and higher in the series, that on reaching the top of High Hill, in Meigs township, we have surmounted *one thousand and ninety feet* of the strata of the Coal-measures. Another interesting fact is revealed, in the valley of Jonathan's creek, in the township of Newton, in the existence of the Newtonville limestone, which lies at the base of the Coal-measures. The Newtonville limestone is the equivalent of the Maxville limestone, found at Maxville, in the southwestern part of Perry county. It is always found resting upon the Logan or Upper Waverly, or in close proximity to it. The dip of the strata from the western edge of the coal-field in western Perry county, is so slight that even the very base of the measures has not been carried down below drainage in the deep Jonathan creek valley. East of the Muskingum river, the dip is greater as seen in the coal mines. But not far from the east line of Muskingum county we find, in places, evidence of a reversed dip. If we follow the line of the Cincinnati and Muskingum Valley Railroad from

the west, we find at Bremen, the Logan or Upper Waverly strata, at the base of all the hills, while at the Tunnel, east of New Lexington, we are several hundred feet up in the Coal-measures. From the east, in the low valley of the Moxahala, we find between the railroad and Newtonville, the Newtonville limestone, which rests upon the Upper Waverly. We thus pass upon the Waverly over several hundred feet of Coal-measures, and down to the Waverly again. The Newtonville limestone is one of the most interesting deposits in the state. It contains many characteristic fossils, by which its equivalency with the Lower Carboniferous limestones of the west has been determined. Prof. Meek who has studied the fossils, regarded them as those characterizing the Chester and St. Louis groups of Illinois and Missouri.

There is not found, generally, any wide marked conglomerate at the base of the Coal-measures in Muskingum county. The conglomerate at Black Hand, which was formerly regarded as a Coal-measures conglomerate, proves to belong to the Waverly formation, as has been shown in former Reports. This Waverly conglomerate is a well marked subdivision of the Waverly group, and has a wide extent.

In Muskingum county, we find in greater or less development nearly every leading coal seam in the *Second Geological District*. Many seams, thick elsewhere, are very thin here, and in one or two instances we find seams thin elsewhere, unusually thick here. This continuity of seams in the same geological horizons, shows how wide spread were the old coal-producing marshes. The lowest coal-seams, of which there are three in Jackson county, of great purity and value, are represented in Muskingum county, only by the merest traces of coal. No seam of coal of much value is found until we rise, in the upward series, to the vicinity of the Putnam Hill limestone, under which is a seam of coal, generally thin and often wanting altogether, but sometimes increasing to a good workable thickness. This is Mr. Porter's coal in Hopewell township, described in the *First Annual Report*, and given again in Sec. No. 15 A, in the Map No. X, of Grouped Sections, of Muskingum county. The same seam has a thickness of 2 ft. 6 in., in Salt Gum Hollow, as shown in Sec. No. 9, on the same Map.

The Putnam Hill limestone is everywhere found in the county at its proper geological horizon, and is an excellent geological guide in finding the positions of strata above and below it.

The next seam of coal above the Putnam Hill limestone, thick enough for working, is what is, in Perry county, termed the lower New Lexington seam. It is probable that the upper coal in Sec. No. 15, in Map No. X., is this seam, although there placed 10 feet below its usual horizon.

Mistakes in measurement are easily made, and increasing experience in our stratigraphical work shows that coal-seams maintain their geological horizons with very remarkable exactness. The reasons for this uniformity will be given in a discussion of the origin of our coal-seams in another part of this Report. The upper New Lexington coal-seam is the equivalent of the Nelsonville seam, and of the great seam at Straitsville and in the upper Sunday creek valley, having in its wide extent through Southern Ohio various fortunes of thickness and quality. Both the upper and lower New Lexington seams are mined near Zanesville.

Higher up we find only traces of the Norris or Middle seam of the Sunday creek valley. Above this we have, in the Alexander coal, the representative of a seam widely spread. The Alexander coal is in some places over 6 feet thick. In Brush creek township, there is a seam 70 feet above the Alexander seam, which is reported to be 4 feet thick, seen in Sec. No. 25 on the Map. In other counties a seam is found on this horizon, but it was not found elsewhere in Muskingum county. About 50 feet higher, or 120 feet above the Alexander seam, is a well defined coal-seam, ever holding its true place in the series, but is generally quite thin. This seam is found in Guernsey county, but not in Morgan.

About 45 feet higher is another seam thick enough to warrant mining for local use, a seam found in several counties, but generally quite thin. This is 25 or 30 feet below the wide-spread fossiliferous limestone which I have called the Ames limestone, from Ames township, Athens county, where it is well developed, and was first described by Doctor Hildreth in the old Geological Reports. This limestone is about 140 feet below the Pomeroy seam of coal. The Pomeroy seam is thin in the southern part of Muskingum county, but it is generally seen in its proper horizon. This seam is to be traced to Gallia county on the south-west, and to Bellair and Wheeling on the east, and the Pennsylvania geologists have traced it to Pittsburgh and identified it with the Pittsburgh and Youghiogheny seam. In Western Pennsylvania several hundred feet of strata below the Pittsburgh seam are destitute of coal-seams of practical value, and hence are called the barren Coal-measures. In Ohio, at least in the Second Geological District, we find more or less coal in this interval. The Nelsonville or Straitsville seam is 420 feet below the Pittsburgh seam, and we often find two and three valuable seams above the Nelsonville one. In Gallia county there is a seam of considerable local value 45 feet below the Pomeroy or Pittsburgh seam.

About 30 feet above the Pomeroy coal are traces in Muskingum county of another coal-seam which is seen in several counties, but with frequent interruptions of continuity. Not far from 100 feet above the Pomeroy

seam is another of wide range, which I have called the Cumberland seam, from Cumberland, Guernsey county, where it is the chief seam worked. The Cumberland seam I have traced through Athens, Morgan, Muskingum, Noble, Washington, Monroe, Guernsey and Belmont counties, and it is a seam of great importance. About 115 feet above the Cumberland seam is one of limited thickness, but of reported good quality, found on High Hill, in Meigs township, Muskingum county. This is the highest seam found in the county, and is 945 feet above the top of the Waverly formation.

Thus we have, in thicker or thinner development, a representation, within the limits of the county, of nearly every important seam of coal in the Coal-measures of Southern Ohio. Of some of these, as of the lower Jackson county coals, we have only hints, but these hints are very significant in showing the wide range of the ancient coal-producing marshes. As each marsh, in which the coal vegetation grew, skirted the ancient ocean, it held its range nearly upon a water-line. As such marsh settled down below the ocean, sands and mud were deposited over it, and a new surface formed for a new marsh. The subsidence being regular and uniform, these marshes form seams of coal which show a natural and almost necessary parallelism.

The number and position of limestones in Muskingum county will best be seen by reference to the Map of grouped sections. The largest deposit is that at Newtonville and vicinity, which is the more interesting because it is the finest representative in Ohio of the great lower Carboniferous limestones of Illinois and Missouri. There is a fossiliferous limestone 80 feet above the Newtonville deposit in Newton township. This was mistaken by one of my assistants in 1869 for the Putnam Hill stratum, a mistake which has led to some confusion. The true Putnam Hill limestone is 72 feet higher. Both of these seams are found at Zanesville (Putnam Hill), the lower being in the bed of the Muskingum at the mouth of the Licking river, and the upper in the Putnam Hill above the road at the dug-way. In the eastern part of the county are other limestone seams, which are higher in the geological series. The exact positions of these will be readily seen from the Map. Some of these limestones are more soluble under atmospheric agencies than others, and hence are more valuable in their fertilizing influence upon soils. Muskingum county is much better supplied with limestone than very many of the counties of the State. The limestone of the Putnam Hill seam is used successfully in the blast furnaces at Zanesville as a flux.

Iron ores of excellent quality are much more abundant in this county

than was formerly supposed. These ores, with analyses of many, will be noticed in the detailed examinations of the townships.

The most interesting feature of the surface geology of the county is the system of drift terraces along the banks of the Muskingum river, the materials of which have been brought from regions to the north. It is my opinion that much the larger part of the materials forming these terraces came down the Muskingum and not down the Licking, but I may be mistaken in this.

HOPEWELL TOWNSHIP.

Reference was made to the more important geological facts observed in this township in the *Geological Report* for 1869. The position of the coals found in the southern part of the township was given, and their relations to the Putnam Hill limestone. In 1871 some additional examinations were made. A mile and a half south-east of Pleasant Valley Station the following section was obtained:

		FEET.	IN.
1.	Compact sandstone	14	0
2.	Shaly sandstone with coal plants	5	0
3.	Hard sandstone	1	0
4.	Bituminous slate	0	10
5.	Coal	0	10
6.	Sandstone	1	0
7.	Clay shale	14	0
8.	Sandstone, laminated at top	35	0
9.	Clay and not seen	5	0
10.	Logan or Upper Waverly sandstone	...	...

The section is seen on Map X., Sec. No. 1.

The following section was taken on the land of William Rodman, Sec. 21:

		FEET.	IN.
1.	Putnam Hill limestone	2	0
2.	Not seen	15	0
3.	Sandstone	25	0
4.	Not seen	12	0
5.	White sandstone	20	0
6.	Shale, with small nodules of siderite ore	2	6
7.	Siderite ore	0	8
8.	Fossiliferous limestone	1	6
9.	Not exposed	15	0
10.	Shale	2	0
11.	Limonite ore	0	10
12.	Shale, with small nodules of limonite ore	7	0
13.	Limonite ore	0	4

See Sec. No. 15, Map X.

The limonite ores in the above section are of good quality, and are used in the Ohio Iron Company's furnace at Zanesville.

A sample of Rodman's limonite ore, obtained at the furnace, was analyzed by Prof. Wormley, as follows:

Specific gravity	2.750
Water combined	9.80
Silicious matter	28.80
Iron, sesquioxide	52.96
Manganese	2.80
Lime, phosphate	0.0
Lime, carbonate	1.43
Magnesia	0.75
Sulphur	Trace.
Total	99.14
Metallic iron	37.07
Phosphoric acid	Trace

This ore, although not very rich in metallic iron, is remarkably pure, containing only chemical traces of sulphur and phosphorus.

The siderite ore is promising, but has not as yet been used to any great extent.

At Martin's Mill, section 15, in this township, the following geological section was taken:

		FEET.	IN.
1.	Potter's clay, not measured	...	...
2.	Not seen	81	0
3.	Blossom of coal	...	...
4.	Not seen	45	0
5.	Blossom of coal	...	...
6.	Sandy shale	16	0
7.	Limonite ore	0	5
8.	Not seen	63	0
9.	Limestone, Maxville	8	0
	Bed of Kent's run	...	...

Iron ores from Hopewell township, are sent to the Zanesville furnace, and samples were obtained there for analysis.

No. 1. Ore from Colvin's bank, near Mt. Sterling.
No. 2. Ore " Riffle's " " Gratiot.

	No. 1.	No. 2.
Specific gravity	3.465	2.783
Water	3.59	11.30
Silicious matter	10.08	9.44
Iron, sesquioxide	14.07	75.07
Iron, carbonate	56.39	0. 0
Alumina	1.00	0.20
Manganese	2.70	0.80
Lime, phosphate	0.67	0.82
Lime, carbonate	5.16	2.05
Magnesia	4.86	0.14
Sulphur	0.54	trace.
Total	99.06	99.72
Metallic iron	37.07	52.51
Phosphoric acid	0.31	

The Gratiot ore is rich in iron, with only 0.38 per cent. of phosphoric acid and a mere trace of sulphur.

FALLS TOWNSHIP.

The following geological section was taken on the land of Henry Flesher:

		FEET.	IN.
1.	Blossom of coal	....	....
2.	Not exposed	92	0
3.	Putnam Hill limestone	1	6
4.	Not exposed	125	0
5.	Sandstone	15	0
6.	Coal, not measured	...	...
7.	Sandstone	30	0
8.	Coal, very thin	0	5
9.	Clay	0	6
10.	Soft, laminated sandstone	15	0
11.	Siderite ore	0	5
12.	Maxville limestone, probably	2	6
13.	Sandstone	5	0
14.	Shale	2	0
15.	Siderite ore, very thin	...	...
16.	Shale	3	0
17.	Siderite ore	0	6
18.	Sandstone, unusually coarse for Waverly	...	...

For this section see Sec. No. 3, Map X.

Some loose fragments of conglomerate were seen on the surface of the ground near the horizon of the Maxville limestone, but no conglomerate was found in place.

The following geological section was taken a mile and a half north-west of Dillon's Falls:

		FEET.	IN.
1.	Clay shale	10	0
2.	Gray limestone, Putnam Hill	2	6
3.	Shale	8	0
4.	Sandstone	35	0
5.	Blossom of coal	...	...
6.	Shale	4	0
7.	Black flint	1	0
8.	Shale	5	0
9.	Blossom of coal	...	...
10.	Fire-clay	3	0

For this section, see Sec. No. 4, Map X.

The following geological section was taken at Dillon's Falls:

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Not exposed	54	0
3.	White clay	3	0
4.	Laminated sandstone	35	0
5.	Putnam Hill limestone, fossiliferous	2	0
6.	Not exposed	33	0
7.	Blossom of coal	...	...
8.	Shale	10	0
9.	Iron ore, not measured	...	...
10.	Black flint	0	10
11.	Not exposed	66	0
12.	Sandstone	12	0
13.	Shale	10	0
14.	Coal, very thin	...	...
15.	Hard sandstone	22	0
16.	Dark shale, with nodules of siderite ore	...	...
17.	Coal, reported to have been dug in the bed of the Licking river	1	6

For this section, see Sec. No. 2, Map X.

The ore in the above section was once dug and used in a furnace at Dillon's Falls. The furnace has long since been abandoned.

The following geological section was taken near the Licking river bridge west of West Zanesville:

		FEET.	IN.
1.	Sandstone, laminated	12	0
2.	Shale	6	0
3.	Limestone, Putnam Hill	2	6
4.	Shale	4	0

		FEET.	IN.
5.	Heavy sandrock, quarried	20	0
6.	Shale	6	0
7.	Coal blossom	—	—
8.	Not seen	4	0
9.	Shale	12	0
10.	Black flint	0	
11.	Limestone, fossiliferous	1	0
12.	Coal	1	6
13.	Under-clay	3	0
14.	Sandstone	1	0
15.	Shale	6	0
16.	Black slate	0	4
17.	Coal	1	3
18.	Under-clay	2	0
19.	Sandstone and shale	5	0
20.	Limestone, fossiliferous	1	0
21.	Shale	2	0
22.	Not seen	1	0
23.	Coarse sandstone	6	0

For this section, see Sec. No. 5, Map X.

The following geological section was taken on the Hollingsworth farm, in Falls township:

		FEET.	IN.
1.	Putnam Hill limestone	2	6
2.	Not exposed	48	0
3.	Flint	0	4
4.	Fossiliferous limestone	0	6
5.	Not exposed	10	0
6.	Siderite ore	0	6
7.	Coal	1	0
8.	Shale	8	0
9.	Cannel slate	0	6
10.	Coal	0	6
11.	Clay	2	0
12.	Shale	6	0
13.	Flinty sandstone	0	2
14.	Sandy shale	2	0
15.	Fossiliferous limestone	1	0
16.	Coal	0	4
17.	Blue clay shale with nodules siderite	20	0
18.	Coal	0	2
19.	Shale	10	0
20.	Sandy shale	6	0
21.	Shale	20	0
22.	Sandstone	4	0

See Sec. No. 12, Map X.

The following geological section was taken on Joe's run, about half a mile north of the Central Ohio Railroad bridge across the Licking river:

		FEET.	IN.
1.	Putnam Hill limestone	1	6
2.	Clay and shale	20	0
3.	Ore, limonite, sometimes siderite	0	5
4.	Flint	0	8
5.	Mostly sandy shale	30	0
6.	Siderite ore	0	5
7.	Flint and limestone, fossiliferous	1	3
8.	Siderite ore	0	6
9.	Dark shale	...	...

On the land of Mr. Kline, the following geological section was taken:

		FEET.	IN.
1.	Limonite ore	0	3
2.	Shale	1	0
3.	Siderite ore	0	6
4.	Limestone, fossiliferous	2	0
5.	Sandy bituminous shale	10	0
6.	Coal	0	3
7.	Clay	0	6
8.	Coal	0	3
9.	Clay	0	2
10.	Coal	0	3
11.	Clay	1	0
12.	Sandy bituminous shale with coal plants	1	0

See Sec. No. 11, Map X.

A sample of Mr. Kline's limonite ore, obtained at the Zanesville furnace, was analyzed by Prof. Wormley, with the following result:

Specific gravity	2.682
Water, combined	11.15
Silicious matter	23.70
Iron sesquioxide	59.04
Manganese	0.85
Lime, phosphate	1.15
Lime, carbonate	1.05
Magnesia	2.06
Sulphur	trace.
Total	99.66
Metallic iron	41.33
Phosphoric acid	0.54

This is a good quality of ore.

ZANESVILLE CORPORATION.

The following geological section was taken on the land of J. Granger, near the forks of Mill run, in the corporate limits of Zanesville:

		Feet.	In.
1.	Shale	6	0
2.	Coal	2	4
3.	Clay	0	1
4.	Coal	0	5
5.	Not exposed	27	0
6.	Coal	4	0
7.	Clay	4	0
8.	Sandstone, quarried	30	0
9.	Coal	2	0
10.	Sandstone	4	0
11.	Shale	10	0
12.	Laminated sandstone	10	0
13.	Shale	5	0
14.	Putnam Hill limestone	2	6
15.	Clay	2	0
16.	Sandstone	12	0

Sec. No. 8, Map X.

On Slago's run, near the brewery, the following section was taken:

		Feet.	In.
1.	Putnam Hill limestone	2	0
2.	Dark shale	2	0
3.	Shale, lighter colored	9	0
4.	Laminated sandstone	4	0
5.	Shale	6	0
6.	Sandstone	4	0
7.	Blue shales with nodules of siderite ore	12	0
8.	Siderite ore	1	2

The following analysis was made of the iron ore on Slago's run, by Prof. Wormley:

Specific gravity	2.571
Combined water	00.00
Silicious matter	10.00
Iron sesquioxide	13.32
Iron carbonate	55.44
Alumina	3.00
Manganese	trace.

Phosphate of lime	7.64
Carbonate of lime	7.39
Carbonate of magnesia	3.02
Sulphur	0.17
Total	99.98
Metallic iron	36.44
Phosphoric acid	3.50

The percentage of phosphoric acid is too large and must contaminate iron made from this ore. An ore found on Marietta street, yielded only 12.56 per cent. of metallic iron.

The following geological section is found on the Adamsville road, a half or three-quarters of a mile north of Mill run:

		FEET.	IN.
1.	Sandstone	3	0
2.	Coal blossom	—	—
3.	Shale	10	0
4.	Finely laminated sandstone	10	0
5.	Heavy crumbling sandstone	14	0
6.	Compact, laminated sandstone	6	0
7.	Coal blossom	—	—
8.	Finely laminated sandstone	34	0
9.	Shale	12	0
10.	Coal	3	0
11.	Not exposed	27	0
12.	Coal	4	0
13.	Not exposed	64	0
14.	Putnam Hill limestone	—	—

See Sec. No. 10, Map X.

A very careful section of Putnam Hill was made by Mr. Gilbert, with measurements as follows:

		FEET.	IN.
1.	Sandstone	4?	0
2.	Buff sandy shale, with nodules of ore	8	0
3.	Fire-clay	2	0
4.	Coal	0	2
5.	Clay	0	6
6.	Coal	1	11
7.	Under-clay	2	0
8.	Buff shaly sandstone	6	0
9.	Buff shale, with nodules of iron ore	8	0
10.	Clay	2	0
11.	Shale	6	0
12.	Nodular limestone	2	0

		FEET.	IN.
13.	Shale	20	0
14.	Coal blossom	...	...
15.	Buff, sandy shale, with nodules of ore	50	0
16.	Putnam Hill limestone, fossiliferous	2	
17.	Sandy bituminous shale, fossiliferous	2	0
18.	Coal	0	10
19.	Shale	8	0
20.	Coal and slate	0	4
21.	Under-clay	3	0
22.	Fine-grained sandstone	4	0
23.	Not exposed	16	0
24.	Clay shale	12	0
25.	Sandy shale	10	0
26.	Clay shale	4	0
27.	Sandstone	4	0
28.	Shale	10	0
29.	Siderite ore	0	4
30.	Limestone, fossiliferous	0	4
31.	Siderite ore	0	5
32.	Limestone, fossiliferous	2	0
33.	Shaly limestone, fossiliferous	0	8
34.	Sandstone	4	0
35.	Low water, Muskingum river	...	...

For this section, see Sec. No. 6, Map X.

A sample of siderite ore from Ives' run, Zanesville, gave the following result of analysis:

Specific gravity	3.250
Water	6.40
Silicious matter	23.28
Iron, sesquioxide	14.58
Iron, carbonate	45.54
Alumina	0.40
Manganese	0.50
Lime, phosphate	0.67
Lime, carbonate	5.16
Magnesia	2.80
Sulphur	0.50
Total	99.83
Metallic iron	32.19
Phosphoric acid	0.31

SPRINGFIELD TOWNSHIP.

On the land of Rev. J. Springer, Sec. 16, the following section was taken:

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Not seen	60	0
3.	Putnam Hill limestone	1	6
4.	Shale	3	0
5.	Sandstone	1	0
6.	Shale	2	0
7.	Coal	1	0
8.	Under-clay	0	6
9.	Sandy shale	10	0
10.	Siderite ore	0	6
11.	Flint	0	10
12.	Dark shale and laminated sandstone	5	-0
13.	Fine-grained sandstone	4	0

The fine-grained sandstone, (No. 13 in the above section,) is a very handsome light-blue stone, very evenly bedded, easily quarried, and has proved to be durable. It is evidently a very valuable building stone.

On the land of Perry Bolin, Sec. 6, in this township, a limonite ore, 6 inches thick, is found at an elevation of 54 feet above the Putnam Hill limestone. This ore is taken to the Zanesville furnace. The following is an analysis of Mr. Bolin's ore, by Prof. Wormley:

Specific gravity	2.624
Water combined	13.20
Silicious matter	14.96
Iron sesquioxide	67.35
Manganese	0.90
Lime, phosphate	0.63
" carbonate	0.81
Magnesia	1.32
Sulphur	trace.
Total	99.57
Metallic iron	47.15
Phosphoric acid	0.29

This is an excellent ore, rich in iron, free from sulphur, and containing only a small amount of phosphorus.

The seam, where measured, averages 6 inches in thickness.

In Springfield township, the two seams of coal known as the two New Lexington coals (the upper of which is the equivalent of the great seam

of southern Perry county) are almost constantly seen in their proper horizons. They are worked in many places. They always hold the same position relatively to the Putnam Hill limestone. The original and typical Putnam Hill limestone is found in this township and is easily examined in the dug-way just above the bridge of the Cincinnati & Muskingum Valley Railroad.

NEWTON TOWNSHIP.

Reference was made to the important geological features of this township in the Annual Report for 1869. The limestone in the bed of Jonathan's creek, the equivalent of the Maxville limestone, and the best representative in the State of the lower Carboniferous limestone of Illinois and Missouri, is a deposit of very great scientific interest. This formation extends several miles above Newtonville on all the leading branches of the creek. In places the upper layers are buff colored, and an analysis of a sample taken near J. Roberts' Sec. 14, showed the presence of considerable magnesia. I copy the analysis by Prof. Wormley, from former Report:

Silicious matter	15.20
Alumina and sesquioxide of iron	4.40
Carbonate of lime	49.80
" of magnesia	30.65
Total	100.05

Probably the whiter and purer portions of the stone contain little else than carbonate of lime. Experiments should be tried with the buff stone to determine the value of its lime for hydraulic purposes.

The fossiliferous limestone 80 feet above the limestone in the bed of the creek is not the Putnam Hill limestone, as might perhaps be inferred from the Report for 1869; the Putnam Hill limestone is 72 feet higher. Sixty-three feet above this is the lower New Lexington coal mined at the Miami Company's mines in Sec. 28. The upper New Lexington seam, the equivalent of the Straitsville or Nelsonville seam, is also mined at the same mines. The seams are 22 feet apart. The lower is 3 feet 10 inches thick, and the upper 4 feet. The coal is generally of excellent quality. I have no doubt that there are in this township workable seams of good iron ore. Such ores are found north and east, and will be found here, when careful search is made.

CLAY TOWNSHIP.

This is a township of very limited area in the south-west corner of the county. Reference was made to it in the Report for 1869. No additional

facts have been obtained since that Report was made. The Putnam Hill limestone is found here, and the upper New Lexington seam of coal is about 80 feet above it. The lower seam had not been found, but it may be there in local developments. It is nowhere a very certain seam. When there is sufficient demand to warrant careful searches, I have little doubt but that valuable iron ore will be found in this vicinity. In other townships good ores are found in similar portions of the Coal-measures series. The most useful material as yet taken from the earth in Clay township, is potter's clay, from which large quantities of excellent pottery are annually made.

BRUSH CREEK TOWNSHIP.

On the land of Mr. Sloan, near Stovertown, Sec. 36, in Brush Creek township, a geological section was made, revealing the Alexander seam of coal:

		FEET.	IN.
1.	Shale	8	0
2.	Coal	1	4
3.	Clay	0	2
4.	Coal	1	6
5.	Under-clay	...	...

On the land of J. Elmore, Sec. 13, the following geological section was taken:

		FEET.	IN.
1.	Sandstone	8	0
2.	Coal, reported thickness	4	0
3.	Mostly laminated sandstone	70	0
4.	Coal, Alexander seam, reported	6	0
5.	Laminated sandstone	45	0
6.	Sandy limestone	1	0
7.	Laminated sandstone	39	0
8.	Blossom of Straitsville or Nelsonville coal	....	...

See Sec. No. 25, Map X.

The two upper coal seams in this section have formerly been opened, but the openings have fallen in, and no measurements could be made. It is possible that the seams are less thick than reported.

WASHINGTON TOWNSHIP

Lies north-east of Zanesville, and is intersected by the Central Ohio Railroad.

The following geological section was taken at Coal Dale and Rocky Point, in this township:

		FEET.	IN.
1.	Shale	...	...
2.	Coal	3	0
3.	Not exposed	24	0
4.	Siderite ore	0	6
5.	Coal	2	9
6.	Under-clay	4	0
7.	Not exposed	13	0
8.	Laminated sandstone	12	0
9.	Heavy sandstone	36	0
10.	Coal blossom	...	...
11.	Siderite ore	0	10
12.	Putnam Hill limestone	5	0
13.	Not exposed	2	0
14.	Laminated sandstone	10	0
15.	Shale	25	0
16.	Cherty limestone	1	0
17.	Slaty cannel coal	0	4
18.	Not exposed	18	0
19.	Blue sandy shale	8	0
20.	Limestone	0	10
21.	Shaly limestone	1	3
22.	Limestone, fossiliferous	1	6
23.	Sandy shale	...	...

See Sec. No. 7, Map X.

In the above section, Nos. 4, 5 and 6 were seen near Coal Dale, and the rest of the section at Rocky Point. In the slate over the upper coal fine *Chonetes* and other fossils, changed to pyrite, are found at Matthews' coal bank, in the north part of this township.

The following geological section was taken near the line between the corporate limits of Zanesville and Washington township. The upper part, containing the Alexander coal-seam. was taken on the land of D. Hart:

		FEET.	IN.
1.	Coal, reported	4	0
2.	Clay	2	6
3.	Laminated sandstone and shale	40	0
4.	Coarse sandstone	10	0
5.	Finely laminated sandstone and shale	30	0
6.	Coal	3	0
7.	Clay	2	0
8.	Laminated sandstone	25	0
9.	Siderite ore	0	10
10.	Shale, bituminous	2	0
11.	Coal	4	0

See Sec. No. 13, Map X.

The following geological section was obtained on the land of Wm. Alexander, on lot 119, Washington township:

		FEET.	IN.
1.	Shale	8	0
2.	Slaty coal	0	10
3.	Clay	0	2
4.	Coal	5	0
5.	Clay	2	0
6.	Sandy limestone	1	0

See Sec. No. 14, Map X.

This coal has a good reputation for household use, and is extensively used along the line of the National Road.

WAYNE TOWNSHIP.

The following section was taken on the land of Nathan Joseph, Sec. 10, Wayne township:

		FEET.	IN.
1.	Shale	3	0
2.	Sandy bituminous shale	3	0
3.	Coal	4	0
4.	Clay	0	2
5.	Coal	2	6
6.	Clay	5	0
7.	Limestone	2	0

See Sec. No. 16, Map X.

The following geological section was seen on the land of Wm. Dunn, Sec. 6, Wayne township:

		FEET.	IN.
1.	Limestone, not measured	...	...
2.	Not exposed	3	0
3.	Coal blossom	...	...
4.	White clay	6	0
5.	Coarse crumbling sandstone	40	0
6.	Coal	3	10
7.	Clay	1	3
8.	Coal	0	10
9.	Clay	5	0
10.	Limestone	2	0
11.	Clay	3	0
12.	Finely laminated sandstone	30	0
13.	Shale	12	0
14.	Bituminous shale and coal	0	6
15.	Shale	5	0
16.	Compact sandstone	10	0

See Sec. No. 17, Map X.

In Sec. 9, in this township, the blossom of the Alexander coal was seen on the road to Chandlersville, with the usual sandy limestone below it. This limestone contains a few fossils. No good openings were found at this point for the measurement of the coal. In Sec. 10, the coal shows a fine development.

In Sec. 7, in this township, the blossom of the Alexander coal was also seen, with the limestone below it.

The following geological section was taken about a mile and a half south-east of Zanesville, in what is called Salt Gum hollow :

		FEET.	IN.
1.	Sandstone	12	0
2.	Blue shale	10	0
3.	Coal	2	0
4.	Clay	0	2
5.	Coal	0	8
6.	Clay	3	0
7.	Sandstone	13	0
8.	Laminated sandstone	35	0
9.	Sandstone	10	0
10.	Shale	5	0
11.	Coal	0	8
12.	Clay	2	0
13.	Slaty coal	0	4
14.	Clay	3	0
15.	Slaty coal	0	6
16.	Clay	3	0
17.	Shale	7	0
18.	Siderite ore	0	5
19.	Shale	15	0
20.	Putnam Hill limestone	2	6
21.	Laminated blue sandstone	10	0
22.	Coal	2	6

See Sec. No. 9, Map X.

HARRISON TOWNSHIP.

Section at Taylorsville :

		FEET.	IN.
1.	Sandstone, quarried	23	0
2.	Not well exposed	54	0
3.	Shale	4	0
4.	Coal, Alexander seam	2	0
5.	Clay	3	0
6.	Sandstone	4	0
7.	Shale, sandy	3	0

		FEET.	IN.
8.	Light bluish sandstone, quarried	68	0
9.	Shale, blue and sandy	4	0
10.	Coal	1	6
11.	Clay	0	1
12.	Coal	0	10
13.	Clay	2	6

See Sec. No. 24, Map X.

At the point where the section was made the Alexander coal was unusually thin. It is reported to be thicker on the east side of the Muskingum river.

The lower coal in the section, which is the equivalent of the Upper New Lexington or Straitsville coal, is worked for neighborhood use.

In Sec. 19, Harrison township, at "Blue Rock," but not in Blue Rock township, the following section was made:

		FEET.	IN.
1.	Sandstone	8	0
2.	Shale	2	0
3.	Coal	0	6
4.	Shale	30	0
5.	Coal, Alexander seam, from 3 ft. 6 in. to	4	0

See Sec. No. 28, Map X.

The lower or Alexander coal has been extensively mined at this point and shipped on the Muskingum river to supply the demands of the salt furnaces and the towns on the river below. It was at this point that the roof of an entry fell in, imprisoning four miners, who were rescued alive after an imprisonment of over thirteen days, during which time they had nothing to eat except the dinner carried in for the first day.

PERRY TOWNSHIP.

The following geological section was obtained on the land of F. Dunn, Little Salt creek, about 2 miles south-west of Bridgeville:

		FEET.	IN.
1.	Laminated sandstone	20	0
2.	Shale	6	0
3.	Coal blossom, Alexander seam	...	...
4.	Shale	5	0
5.	Limonite ore	0	5
6.	Shale	1	0
7.	Limestone	1	0
8.	Shale	5	0

		Feet.	In.
9.	Clay and ore	2	6
10.	Shale	2	0
11.	Coal	0	2
12.	Clay	2	0
13.	Laminated sandstone, with compact sandstone below	50	0
14.	Cannel coal	0	8
15.	Coal	0	6
16.	Clay	1	6
17.	Shale	20	0
18.	Coal	2	0
19.	Shale	3	0
20.	Sandy limestone and siderite ore	1	6
21.	Laminated sandstone	10	0
	Bed of Little Salt creek.		

See Sec. No. 18, Map X.

On the land of W. Dunn, a half mile east of F. Dunn's, was taken the following section:

		Feet.	In.
1.	Laminated sandstone	6	0
2.	Black slate	0	10
3.	Coal, Caldwell coal, Alexander seam	2	11
4.	Under-clay and shale	.	.
5.	Not seen	7	0
5.	Limestone and siderite ore	.	.

See Sec. No. 20, Map X.

The coal from the bank of Mr. Dunn was analyzed by Prof. Wormley with the following result:

Specific gravity	1.252
Water	6.15
Ash	4.41
Volatile matter	30.97
Fixed carbon	58.47
Total	100.00
Sulphur	0.41

The analysis shows this to be a very superior coal. The fixed carbon is large and the sulphur small. It has been tried, in a small way, in the Zanesville furnace with approval. So far as analyses have been made, this coal is found to be the purest in that part of the county belonging

to the Second District, and is one of the best coals of the State. At many other points the coal of this seam is much less pure.

The following geological section was taken on the land of Mr. Crane, about a mile south of F. Dunn's, near the line between Perry and Salt creek townships:

		FEET.	IN.
1.	Sandstone	3	0
2.	Shale	6	0
3.	Black slate	0	5
4.	Coal, Alexander seam	3	0
5.	Clay and shale	6	0
6.	Limestone	1	0
7.	Not seen	10	0
8.	Laminated sandstone	15	0
9.	Heavy sandstone	30	0
10.	Coal	0	2
11.	Shale	4	0
12.	Sandstone	1	0
13	Cannel slate and coal	1	0
14.	Shale	15	0
15.	Finely laminated sandstone	8	0

See Sec. No. 34, Map X.

The coal, No. 4 in this section, could not be examined, the old opening having fallen in.

UNION TOWNSHIP.

The following geological section was obtained about half a mile west of the village of Norwich:

		FEET.	IN.
1.	Limestone, fossiliferous and ferruginous	2	6
2.	Not exposed	2	0
3.	Laminated sandstone	20	0
4.	Shale	5	0
5.	Coal	1	3
6.	Clay	0	2
7.	Coal	1	3
8.	Clay	0	2
9.	Mostly laminated sandstone	40	0
10.	Not seen	4	0
11.	Coal blossom	.	.

See Sec. No. 23, Map X.

At Norwich station the following strata were exposed:

		FEET.	IN.
1.	Coal	2	6
2.	Under-clay, not measured	...	...
3.	Laminated sandstone	29	0
4.	Conglomerate sandstone, with small quartz pebbles	6	0
5.	Sandy iron ore, limonite	1	0
6.	Clay shale	3	0
7.	Not exposed	7	0
8.	Blossom of coal	...	...

The upper coal in this section is the same as the upper in the last.

The following geological section was obtained in Sec. 16, Union township:

		FEET.	IN.
1.	Limestone	1	0
2.	Not exposed	40	0
3.	Coal, blossom	...	...
4.	Limestone	1	0
5.	Laminated sandstone	27	0
6.	White limestone	2	0
7.	Red shale	25	0
8.	Coal, blossom	...	...
9.	Not exposed	80	0
10.	Finely laminated sandstone and shale	40	0
11.	Coal, blossom	...	...
12.	Not exposed	10	0
13.	Coarse sandstone	15	0
14.	Laminated sandstone	21	0
15.	Coal, blossom	...	...

See Sec. No. 26, Map X.

The following geological section was obtained in a railroad cut, at the summit, between the waters of Muskingum and Wills creek, about a mile east of Norwich:

		FEET.	IN.
1.	Limestone	1	0
2.	Shale	5	0
3.	Lime	1	6
4.	Shale	3	6
5.	Limestone	1	0
6.	Red shale	10	0
7.	Mostly reddish shale	52	0
8.	Blue shale	10	0
9.	Iron ore and limestone	0	4
10.	Shale	11	0
11.	Not exposed	24	0
12.	Limestone, fossiliferous	2	0

See Sec. 22, Map X.

In Sec. 10, Union township, was obtained the following section:

		FEET.	IN.
1.	White crumbling limestone	1	0
2.	Not exposed	18	0
3.	Blossom of coal	...	...
4.	Limestone	1	0
5.	Not exposed	20	0
6.	Blossom of coal	...	...
7.	Not exposed	30	0
8.	Blossom of coal	...	...
9.	Bluish limestone	2	0
10.	Not exposed	145	0
11.	Limestone, fossiliferous	1	0
12.	Not exposed	20	0
13.	Clay shale	6	0
14.	Coal	2	4
15.	Clay	0	11
16.	Coal	0	3

See Sec. 30, Map X.

The following geological section was taken about a mile south-west of Concord Station, in Sec. 9 of this township:

		FEET.	IN.
1.	Blossom of coal	...	...
2.	Not exposed	36	0
3.	Blossom of coal	...	...
4.	Limestone	1	6
5.	Not exposed	85	0
6.	Limestone, not measured	...	...
7.	Red shales	60	0
8.	Limestone, fossiliferous	1	0
9.	Not exposed	20	0
10.	Clay shale	6	0
11.	Coal	2	4
12.	Clay	0	11
13.	Coal	0	3

For this section, see Sec. No. 36, Map X.

The following geological section was obtained at the railroad cut, a little east of Concord, and in that neighborhood:

		FEET.	IN.
1.	Limestone	1	6
2.	Red shale at top, bottom not seen	60	0
3.	Limestone, fossiliferous, not measured	...	...
4.	Not exposed	49	0
5.	Laminated sandstone	10	0
6.	Shale	18	0
7.	Coal, not measured	...	...

		FEET.	IN.
8.	Clay and shale	10	0
9.	Limestone, flinty and sandy, fossiliferous	12	0
10.	Hard clay, with nodules of limestone	5	0
11.	Shale	3	0
	Level Central Ohio railroad.		

See Sec. No. 37, Map X.

SALT CREEK TOWNSHIP.

The following geological section was obtained in Sec. 13, Salt Creek township:

		FEET.	IN.
1.	Heavy sandstone	20	0
2.	Coal	2	0
3.	Clay	2	0
4.	Not exposed	40	0
5.	Clay and iron ore	2	10
6.	Shale	11	0
7.	Limestone and iron ore	0	10
8.	Shale, with nodules of siderite ore	6	0
	Bed of Salt Creek.		

See Sec. No. 21, Map X.

The following geological section was obtained on the land of J. A. Clapper, Sec. 8, in this township:

		FEET.	IN.
1.	Finely laminated sandstone	6	0
2.	Ferruginous shale, with nodules of siderite ore	6	0
3.	Finely laminated black slate	0	7
4.	Coal, Alexander seam	3	1
5.	Clay	5	0
6.	Limestone	1	0
7.	Highly ferruginous limestone, changing in places to siderite ore	2	0

See Sec. No. 29, Map X.

This limestone, with its contained iron, might perhaps serve a good purpose as a flux in a blast furnace.

The following geological section was obtained in the hill by L. Pierce's, Sec. 11, Salt Creek township:

		FEET.	IN.
1.	Buff shale	48	0
2.	Coal, reported thickness	2	6
3.	Clay	3	0
4.	Not exposed	4	0
5.	Shale	20	0
6.	Sandstone	4	0
7.	Shale	30	0
8.	Clay and iron ore	0	6

		FEET.	IN.
9.	Shale	11	0
10.	Coal blossom	...	...
11.	Clay	5	0
12.	Not exposed	19	0
13.	Finely laminated sandstone	22	0
14.	Not exposed	5	0
15.	Coal blossom	....	....
16.	Clay	5	0
17.	Coarse sandstone	14	0
18.	Shale	15	0

See Sec. No. 19, Map X.

RICH HILL TOWNSHIP.

The following geological section was taken in Sec. 8, in this township, on the land of Aaron Robinson:

		FEET.	IN.
1.	Heavy sandstone	4	0
2.	Clay shale	6	0
3.	Coal	2	5
4.	Clay	2	0
5.	Whitish limestone	1	0
6.	Not exposed	205	0
7.	Coarse sandstone	10	0
8.	Conglomerate sandstone with fine quartz pebbles	1	0
9.	Shale	5	0
10.	Coal	2	4

See Sec. No. 32, Map X.

The upper coal in this section is used in the neighborhood. The lower coal was not worked at the time of our visit, although an old opening was seen. The upper coal doubtless is the equivalent of the Pomeroy seam.

In Sec. 19, in this township, the following geological section was taken:

		FEET.	IN.
1.	Heavy sandstone	10	0
2.	Bituminous shale	1	5
3.	Coal	2	6
4.	Not exposed	26	0
5.	Clay shales, with nodules of siderite ore	24	0
6.	Calcareous iron ore	0	10

In the same section, on the land of Llewellyn Warne, was found the following geological section:

		FEET.	IN.
1.	Limestone, fossiliferous	2	0
2.	Not exposed	44	0
3.	Heavy sandstone, quarried	6	0

		FEET.	IN.
4.	Sandy iron ore, limonite	0	3
5.	Clay shale	15	0
6.	Black bituminous shale	7	
7.	Coal, reported thickness	2	6
8.	Hard white clay	2	0

The old opening into the coal in this section had fallen in, and no measurements could be made.

In Sec. 20, in the same township, the fossiliferous limestone was seen with 4 inches of siderite ore upon it. The limestone was 3½ feet thick.

Near Rixville, in this township, the following section was obtained:

		FEET.	IN.
1.	Sandy limestone	0	8
2.	Laminated sandstone	27	0
3.	Shale	6	0
4.	Coal, upper 6 in. slaty	3	6
5.	Clay	0	1
6.	Coal	1	0
7.	Under-clay	2	0
8.	Clay shale	12	0
9.	Whitish limestone	2	0
10.	Not exposed	69	0
11.	Blossom of coal	...	...

The upper coal is the one used exclusively in this region, and has an excellent reputation. It is doubtless the geological equivalent of the Pomeroy seam.

In Sec. 21, in this township, the following strata were seen:

		FEET.	IN.
1.	White Limestone	1	6
2.	Not exposed	25	0
3.	Clay shale	9	0
4.	Coal	3	8
5.	Not exposed	58	0
6.	Laminated sandstone	37	0
7.	Not exposed	8	0
8.	Blossom of coal	...	...
9.	Not exposed	122	0
10.	Limestone and iron ore	1	6
11.	Clay shale	16	0
12.	Siderite		4
13.	Limestone, fossiliferous	3	0
14.	Not exposed	5	0
15.	Clay shale	8	0
16.	Black bituminous shale	0	6
17.	Coal, reported thickness	1	

See Sec. No. 27, Map X.

The upper coal in this section is worked. It is the equivalent of the Cumberland coal of Guernsey county.

BLUE ROCK TOWNSHIP.

A geological section was taken near Confederate Cross Roads, in Sec. 3, Blue Rock township, as follows:

		FEET.	IN.
1.	Limestone, clay and iron ore	1	0
2.	Shale	15	0
3.	Fossiliferous limestone, Ames limestone	1	2
4.	Laminated sandstone	30	0
5.	Blossom of coal	...	...
6.	Laminated sandstone	20	0
7.	Shale	20	0
8.	Sandy shale, bituminous	4	0
9.	Coal	2	0
10.	Under-clay	...	...

See Sec. No. 33, Map X.

The lower coal in this section is mined for neighborhood use.

Near Rural Dale, in the same township, the following section was taken:

		FEET.	IN.
1.	Laminated sandstone	10	0
2.	Buff limestone	2	0
3.	Shale	40	0
4.	Whitish limestone	1	0
5.	Shale	18	0
6.	Whitish limestone	2	0
7.	Shale	27	0
8.	Black slate	0	6
9.	Coal, Hunter's bank	4	0
10.	Clay	3	0
11.	Nodules of limestone	...	...
12.	Not exposed	58	0
13.	Limestone	3	0
14.	Shales, mostly	54	0
15.	Bluish limestone	2	0
16.	Not exposed	69	0
17.	Sandstone	10	0
18.	Shale	40	0
19.	Limestone fossiliferous, Ames limestone	2	0
20.	Blue shale	10	0

See Sec. No. 35, Map X.

By the barometer, the Hunter's bank was 427 feet above low water of the Muskingum river at Gaysport. The coal is mined for local use, and is held in high esteem. The seam is the same as the Cumberland seam, and is found at its proper horizon in Athens, Morgan, Muskingum, Noble, Guernsey, Belmont and other counties.

In this township many wells were bored for petroleum during the oil excitement in 1864, and, perhaps, earlier. By reference to the section taken near Rural Dale, it will be seen that the fossiliferous limestone in the deep valley is the Ames limestone. This limestone stratum extends through Morgan and Athens counties. In both counties oil in considerable quantities has been found in strata lying from 70 to 150 feet below this limestone. I have been unable to obtain any authentic records of borings in Blue Rock township, but it is probable that what oil was obtained there came from proximately the same geological horizon. During the progress of the Survey, it has been found that the rocks to the east of this township have a western dip. I regard it as probable that the oil in Blue Rock is found along a synclinal line, where the eastern dip meets the western dip referred to. Of late years very little attention has been given to the production of oil in this township.

MEIGS TOWNSHIP.

This township contains High Hill, the highest point in this part of the State. The following section, extending from the top of High Hill, is in Sec. 4 of the township:

		FEET.	IN.
1.	Laminated sandstone and red shale	20	0
2.	Red shale	10	0
3.	Laminated sandstone	10	0
4.	Whitish limestone	2	0
5.	Not exposed	81	0
6.	Coarse sandstone	20	0
7.	Black bituminous shale	0	4
8.	Coal	1	6
9.	Clay	1	0
10.	Blue limestone	2	6
11.	Not exposed	78	0
12.	White limestone	1	0
13.	Not exposed	28	0
14.	Laminated sandstone	3	0
15.	Coal	1	11
16.	Clay parting	0	1
17.	Coal	1	3
18.	Black shale with coal plants	0	6

		FEET.	IN.
19.	Coal	1	5
20.	Clay	2	0
21.	Dark blue limestone	4	0
22.	Not exposed	12	0
23.	White limestone	2	0
24.	Hard fire-clay, seen	1	0

See Sec. No. 31, Map X.

The upper coal in this section is thin, but of fine quality. The coal below, in its various parts, constitutes the Cumberland seam. There are mounds on the very summit of High Hill, this very prominent point having attracted the attention of the mound-builder race. No section could be obtained showing any lower coals. There was difficulty to find exposures.

The following statistics of the Zanesville furnace have been kindly furnished by Gen. Samuel Thomas. The furnace has proved one of the most successful and profitable of the West:

"The Zanesville Furnace, belonging to the Ohio Iron Company, located on the Muskingum river, just above the city, was blown in September 7th, 1871.

"It was built by Samuel Thomas and has proved a very successful furnace. Height of stack sixty-two feet; width at top of boshes sixteen feet; is worked with a close top, and blown with an upright engine of three hundred horse power. It is supplied with hot air passing through three thirty-two pipe stoves, which maintain an average heat of about 900 degrees. Seven three and a half inch tuyers are used, and at these tuyers the pressure of blast is about four pounds.

"The furnace made, the first twelve months run, a small quantity over 12,000 tons of iron. The fuel used has been 1,200 lbs. of Straitsville coal to 600 lbs. of Connelsville coke. The average burthen of ores to the above amount of fuel has been 700 lbs. of native ores from Perry county, 800 lbs. of rich ores from Lake Superior regions, and 150 lbs. of mill cinder. To flux this, 650 lbs. of lime were required. Lime, sand and clay come from the neighboring hills. This furnace is now in blast, (February, 1873,) having been in continuous operation for nearly 18 months, and is making an average of forty tons per day. The stock house, casting house and engine house are built of brick and stone. All the arrangements for receiving coal, coke and ores, as well as shipping iron, are of the most convenient character."

The same Company owns a rolling mill and a small charcoal blast furnace. The rolling mill is in successful operation. The present officers of the Ohio Iron Company are: President, E. E. Fillmore; Treasurer and General Manager, M. Churchill; Secretary, C. W. Greene.

REGISTER OF MUSKINGUM COUNTY.

No.		
1.	Geological Section	1½ miles S. E. Pleasant Valley station, Hopewell township.
2.	"	at Dillon's Falls, Falls township.
3.	"	on land of Henry Flesher, Falls township.
4.	"	1½ miles north-west of Dillon's Falls, Falls township.
5.	"	near Licking river bridge, west of West Zanesville.
6.	"	on Putnam Hill, Putnam, now Zanesville.
7.	Combined Section	at Coal Dale and Rocky Point, Washington township.
8.	Geological Section	on land of J. Granger, near forks of Mill Run, Zanesville.
9.	"	in Salt Gum Hollow, Wayne township.
10.	"	on Adamsville road, ½ mile north Mill Run, Zanesville.
11.	"	on land of Mr. Kline, Falls township.
12.	"	on Mr. Hollingsworth's land, Falls township.
13.	"	near Washington and Zanesville line, upper coal on land of D. Hart.
14.	"	on land of Wm. Alexander, on Lot 119, Washington township.
15.	"	on land of Wm. Rodman, Sec. 21, Hopewell township.
15 A.	"	Joseph Porter's 100 acre Lot No. 16, Hopewell township.
16.	"	on land of Nathan Joseph, Sec. 10, Wayne township.
17.	"	on land of William Dunn, Sec. 6, Wayne township.
18.	"	on land of F. Dunn in Little Salt Creek, 2 miles south-west of Bridgeville, Perry township.
19.	"	near L. Pierce's Sec. 11, Salt Creek township.
20.	"	land of W. Dunn, (½ mile east of F. Dunn's), Perry township.
21.	"	1½ miles east of Chandlersville, Sec. 13, Salt Creek township.
22.	"	railroad cut at summit, a mile east of Norwich, Union township.
23.	"	half mile west of Norwich, Union township.
24.	"	at Taylorsville, Harrison township.
25.	"	on land of J. Elmore, Sec. 13, Brush Creek township.
26.	"	obtained in Sec. 16, Union township.
27.	"	in Sec. 22, Rich Hill township.
28.	"	at "Blue Rock," in Sec. 19, Harrison township.
29.	"	on land of J. A. Clapper, Sec. 8, Rich Hill township.
30.	"	in Sec. 10, Union township.
31.	"	on High Hill, Sec. 4, Meigs township.
32.	"	on land of Aaron Robinson, Sec. 8, Rich Hill township.
33.	"	near Confederate Cross Roads, Sec. 3, Blue Rock township.
34.	"	on land of M. Crane, a mile south of F. Dunn's, near line between Perry and Salt Creek townships.
35.	"	near Rural Dale, Blue Rock township.
36.	"	1 mile southwest of Concord station, Sec. 9, Union township.
37.	"	at railroad cut, ½ mile east of Concord, and neighborhood.

SOME CONCLUSIONS THEORETICAL AND PRACTICAL.

In the *First and Second Annual Reports* more or less complete details have been given of the geology of nearly all of the counties in the western part of the Second Geological District. I may therefore briefly refer to some Formations noticed in former Reports.

The Waverly sandstone group, measuring 640 feet in vertical thickness where it is crossed by the Ohio river, is made up of evenly bedded layers of sandstone with interstratified beds of sandy and clayey shales. About 130 feet above the base of the group is a stratum, 16 feet thick, of a highly bituminous black slate containing remains of fishes, *Lingulæ* and *Discinæ*. This is the only break in the continuity of the hundreds of feet of sandstones and shales, and shows a very remarkable change in the character of the sediments and conditions of deposition. For a time the shallow waters over a considerable area were comparatively quiet, and in them lived such quantities of organic forms, animal or vegetable, as to form by their decomposition bitumen enough to constitute twenty per cent. of the whole mass. The beautiful lamination of the slate shows that the accumulation of the sediments was very slow and by distinct increments. The whole Waverly group, as seen along the Ohio river, was evidently formed in shallow water. The layers of sandstone everywhere show ripple marks, and on many layers we find striæ such as might have been made by the steady movement of ice upon the sandy mud of the bottom. These striæ are very regular, and nowhere indicate that the ice was in broken and confused masses and driven by strong winds and waves upon a shore. The direction of the ripple marks, as seen upon many distinct layers of sandstone, I found to be north, fifty degrees west. The general direction of the striæ is reported to be at right angles to that of the ripple marks. In the middle and lower portions of the Waverly group we find the beds of sandstone, and often the more sandy shales, thickly strewn with impressions of stalks and branches of marine plants, and with myriads of the curiously contorted leaves of the *Spyrophyton cauda galli* and other allied forms. The range of *Spirophyton* is very great. I have found it several hundred feet above the base of the Productive Coal-measures in Southern Ohio, and in New York its abundance gives the name "Cauda Galli Grit" to a member of the Devonian formation. I have found few animal fossils in the lower portion of the Waverly group, but in certain layers in the central and upper portion, such remains are very abundant, and many interesting forms have been furnished Mr. Meek for study and description. I have in a few cases found what were perhaps the tracks of crustaceans.

As we follow the formation towards the north, we find, in Hocking, Fairfield and Licking counties, the middle part changed into a heavy Conglomerate, which is seen in the cliffs along the Hocking and Licking rivers, adding greatly to the attractiveness of the scenery.

It is probable that there was a long period of repose and freedom from those dynamic agencies of subsidence which depress the crust of the earth, after the depotion of the vast sandy flats now constituting the Waverly strata. During this period there was doubtless more or less erosion of the surface, and it was brought into comparatively uneven condition. Whether the thin beds of the Maxville limestone were

deposited before this erosion took place, and so shared in it as now to be left in isolated patches, or were deposited at first in limited basins, is as yet undetermined. The Maxville limestone always rests proximately upon the Waverly group. It is at some points rich in fossils of the lower Carboniferous limestones of the West. Mr. Meek, who has studied them thus far, finds them identical with those found in the Chester and St. Louis limestones of Illinois and Missouri.

Passing upward in the series, we reach the Productive Coal-measures. In places, however, we find an intervening conglomerate. The transition from the Waverly to the Coal-measures, shows an entire change in the lithological character of the strata, and in the methods of distribution of the sedimentary materials. The Waverly materials were evidently derived from some shore, where there was great lithological sameness, and they were spread out with wonderful evenness upon the ocean floor. This floor was level to begin with, for it was formed by the evenly accumulated mass of semi-organic matter, which now constitutes the great Ohio Black Slate or Huron Shales. The materials of sand and clays would of necessity be evenly spread, because their accumulation so perfectly balanced the general subsidence as to keep the incoming materials always in shallow water, and hence, just where the leveling power of the waves would be the greatest.

The Conglomerate is, in Jackson county, a very remarkable deposit of sand and pebbles. In some places, it is over one hundred and thirty feet thick, resting upon the Waverly, and in a short distance, it is completely thinned out to nothing. The pebbles are often a mass of white quartz, or perfectly pure quartzite, sometimes with a diameter of several inches. They tell a tale of rough water and powerful currents. But such deposits are local, and I find no proof whatever that a conglomerate stratum constitutes the regular and continuous floor on which the Productive Coal-measures of the Second District were laid. I find in Ohio, many conglomerates in the Coal-measures, at different horizons, none indeed so coarse as the one sometimes found resting on the Waverly, but they all have a limited horizontal range. They thin out and pass into finer sandstones, and often into shales formed of fine sedimentary mud. In the Coal-measures of the Second District, no sandrock, so far as I know, extends through the whole line of the outcrop of the formation. Both conglomerates and finer-grained sandstones are very uncertain in their horizontal ranges. The same is true of the shales and clays. We have almost all possible forms of sedimentary materials, and in almost all possible conditions of deposition. Hence, frequent changes are to be met with along the same geological horizon. The only strata showing continuity over great horizontal spaces are the coal-seams with their under-clays, and certain fossiliferous limestones. The unfossiliferous limestones of the Productive Coal-measures, which were deposited as a calcareous mud, are of very limited horizontal extent. The unusually thick group of limestones over the Wheeling coal, at Wheeling, W. Va., and at Bellair, in Belmont county, Ohio, are scarcely found farther west in Muskingum county, and to the southwest, in Meigs county, they have no representation whatever. We may find limestones of this class from 10 to 30 feet thick in one place, and a few miles away, in the same horizon, there is not a trace of them to be found. They were formed of calcareous mud and follow in their distribution the same laws of the distribution of the other mud-rocks of the Coal-measures. None of them were of deep water origin, for they not only sometimes exhibit surface dried cracks, but they are found between, and in proximity to, seams of coal which were sub-aerial in origin. All the various strata which constitute the filling in of the spaces

between seams of coal, whether formed from gravels, sands, clays or limestones—excepting three or four fossiliferous limestones,—are subject to all those changes which would be expected in off-shore deposits, where the not very far distant land afforded many kinds of materials, and where the waters, not very deep, were quiet in some places and rough in others, and thus produced every possible variety of deposition.

The few fossiliferous limestones of the Coal-measures, of which the Putnam Hill, Ferriferous, Cambridge and Ames limestones are the most important and interesting, were all formed, I think, in quite shallow, and at the same time quiet waters, from the accumulation of lime-secreting animals. In each case there was probably an arrest of the progress of subsidence long enough for the accumulation of calcareous organic matter to form the stratum of limestone, very much as in the formation of a seam of coal there was an arrest of subsidence and a pause long enough for the growth and accumulation of the vegetable matter constituting the coal. Some of these limestones were formed upon a sea-bed almost perfectly level and uniform, and show a remarkable parallelism with each other and with seams of coal. It is, however, the coal itself which presents the most interesting object of investigation in the Second District, and it is to this subject I have devoted the most attention. I shall present some of the results of my own independent observations relative to the origin, varieties and uses of coals, believing, however, that the views are in essential harmony with the accepted opinions of our better geologists.*

Notwithstanding the elaborate attempt of Bischoff† and others, to prove that coal is an accumulation of vegetable detritus, drifted by rivers and buried beneath accumulating sediments in the ocean, this view is not now accepted by any who have carefully studied the coal-seams in the Coal-measures in America. Mr. Leo Lesquereux and Dr. Dawson have shown, as the results of careful and extended observations, that the vegetation forming seams of coal grew where it is now buried, the only movement being downward in the general subsidence. After such subsidence, sedimentary materials were brought in over the vegetable mass, filling up the water so as to form, in time, a new sub-aerial surface, on which new vegetation took root and grew, to form in turn, when buried, another seam of coal. My own independent observations, continued through many years, convince me that in no other way were the seams of coal in our true Coal-measures formed. There is, moreover, every evidence that the vegetation grew upon marshy plains, more or less extensive, skirting the ocean, or, perhaps, often constituting low islands not far from an ancient shore. This appears from the fact that the slates and shales accompanying the coal, and in immediate proximity to it, often contain marine or brackish-water forms of later palæozoic life. These slates sometimes constitute partings in the coal-seam itself, and extend for miles, maintaining with wonderful exactness their stratigraphical position. These partings imply a temporary overflow of the ancient marsh by the ocean, and an even distribution of sediment, which, when compressed, constitutes the thin layer of slate or clay. Besides, we find in the very coal itself, and especially in the cannel portions of seams,—for

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* Some of the views here given were presented in a paper read before the American Association for the Advancement of Science, at its Annual Meeting at Dubuque, in August, 1872.

† Bischoff abandoned this view in his later years.

cannel coal is, so far as my observations go, only a local modification of a regular bituminous coal-seam,—marine forms of ancient life, of which *Lingulæ* and fishes are, perhaps, most common. We also find in some seams of coal the evidences of tidal or other overflow of the coal-marsh, in beach-worn sticks and various forms of wood, which, now changed to bi-sulphide of iron, are preserved in their original form, and lie in the coal as they were drifted into the old marsh. After the complete subsidence of the whole marsh, we often find the proofs that such trees as *Sigillaria*, *Lepidodendron* and taller ferns were broken down where they grew by the incoming waters, and buried on the spot by the sediments. I once traced the trunk of a *Sigillaria* in the roof of the Pomeroy seam of coal, for a distance of more than forty feet. Thousands of the trunks of what Mr. Lesquereux takes to be *Pecopteris arborescens* are found in the slates over the same coal, lying in horizontal burial as they were bent or broken down by the waters which also brought in their stony winding-sheet. In making almost thousands of geological sections in our Coal-measures, I have found seams of coal always maintaining such relations to what were the ancient water levels, that I am fully convinced that in every case the vegetation grew along the water-line and not far above it.

I have never found the slightest proof of the formation of a seam of coal over hills or high grounds. The parallelism of the seams, of which further mention will be made, forbids it. Doubtless, vegetation of certain kinds grew on the higher grounds, but this vegetation did not constitute seams of coal. It is plain that whatever vegetable matter there might be on a hill-side would in the subsidence of the land present to the waves of the encroaching sea an easy prey, and the trees and humbler plants would be torn from their exposed moorings, and be drifted away to rot upon the waters or be buried in the sands of the beach.

Such drifted and buried trees are frequently found. Should there have been some high level plateau, on which vegetation grew, and which in the subsidence was let down below the water so evenly as to prevent the waters from tearing the vegetable materials away, it is still doubtful whether, on such high and dry areas, there would have been any considerable accumulation of vegetable matter, the decay so equalling the growth that, in reality, there would have been no materials for a true seam of coal.

While the vegetation forming the coal-seams grew upon marshy savannahs skirting the ocean, we find constant proof that the continuity of the marsh was often broken by intervening water, so that the seam of coal is frequently interrupted. In the subsequent subsidence these water spaces were filled up with sands or clays, which are now hardened and compressed into shales and sandstones. But if we have a marsh at one point which continued long enough to allow of the accumulation of vegetable matter sufficient for a considerable seam of coal, the presumption is that on that exact horizon we shall find that there were other areas above the water on which vegetation also grew, and thus along one water-line there be formed a seam of coal, varying in its fortunes of thickness and quality, ranging, with many interruptions, through many counties and perhaps hundreds of miles. A long period of rest from downward movement, such as the growth and accumulation of a thick seam of coal imply, almost necessitates the fact that, during that long period, wherever there were along the water-line areas of low-land, whether insular or continental fringes, on which vegetation might take root and grow, there would be such growth, and consequently a

seam of coal. We, in fact, find this to be the case, so that, in tracing a seam of coal, we learn where the water spaces were, and where even the smaller channel-ways extended through the ancient marshes. These water spaces, wider or narrower, we are able to cross, preserving accurately the level, and thus find the coal at other points always in the same geological horizon.

When the subsidence took place, by which the marsh or marshes of one horizontal line were lowered beneath the water, the presumption is that such subsidence would be an even and regular one. We can hardly suppose that, within any limited area, there would be any considerable inequality in the sinking, any irregular plunges downward here and there, so as to tilt at various angles the plane of the coal. The subsidence was of course greater in some districts than in others. In Nova Scotia there are 14,570 feet of productive Coal-measures, with over 80 distinct seams of coal; in Eastern Pennsylvania 3,000 feet are reported; while in Southern Ohio the highest coal-seam yet found is about 1,500 feet above the Waverly sandstone, on which, at places, a seam of coal with its under-clay is found to rest, with no intervening conglomerate. It is also entirely possible that, when any *large areas* of any one coal-field are carefully investigated, it will be found that some portion of such large area may have had a somewhat more rapid subsidence than the rest.* But, as a rule, the subsidence was so regular that two seams of coal, each formed on its water-line, are found to present an almost perfect parallelism. For example, in Ohio, the Nelsonville seam of coal is found, in the vertical series, to be about 420 feet below the Pomeroy seam, the equivalent of the Wheeling and Pittsburgh seam. These two seams range through many counties, and everywhere the interval between them is the same. The same is true of all our other well-defined and continuous seams. One careful measurement of the interval between two seams is so excellent a guide that, either seam being found, the place of the other can be readily determined. There may be difficulty in ascertaining the exact interval, because there may be considerable horizontal distance between the exposures of the seams, and calculations must generally be made for the dip, usually an unknown term; but when the measurements are accurate the parallelism is perfect and beautiful. There is a little play of variation sometimes, but it is generally very slight. In limited areas the downward movement could hardly be otherwise than uniform. Even in cases of earthquake action, we generally find the areas of elevation or subsidence to be quite extensive. But there is no proof that in the Coal Period there was any intense earthquake action, nor any convulsive disturbances which would give to the plane of a coal-seam great irregularities in inclination. It must be remembered that the elevation of the Alleghenies and the foldings of the Appalachian region and all the thousand undulations given to the strata of our coal-fields were subsequent to the formation of our Coal-measures. The results of the most careful observations in all our coal-fields create a reasonable belief that the subsidence was semi-continental in character, and that the crust of the earth settled down in an even and dignified way.

So far as my own observations go, I have never found an instance where two distinct seams of coal came together, or conversely, where a seam became divided and its parts continued to diverge for a long or indefinite distance. It is not uncommon to find, in a seam of coal, the proof that the coal-marsh had in it local depressions, which were

*I have myself reported a case of this kind in Ohio, during the earlier portion of the Coal Period, but the supposed proofs of this are undergoing careful revision.

filled with sediment, making a soil on which new vegetation grew, and thus the seam shows two parts, separated by fire-clay, sometimes several feet thick; but in every instance, when traced, I have found the parts to re-unite. The two parts never diverge indefinitely. From these statements we may infer a general law of parallelism. Such law is in harmony with the belief of the most careful observers, that our productive Coal Period was characterized by great quietness and freedom from violent local disturbances.

Mr. Lesquereux, who has visited the Dismal Swamp in south-eastern Virginia, reports that the Drummond Lake, which is fifteen feet deep, has beneath it the usual vegetable matter characterizing the bed of the surrounding swamp. Now, if this lake were filled up with earthy sediments and swamp vegetation should grow and accumulate over them, and afterwards the whole vegetable matter of the entire swamp were buried and changed to coal, we should have in the central area a divided seam or two parts of one general seam. If, by some more recent eroding agency, half of the whole area, including half of the area once occupied by the lake were swept away, we might find the two parts of the seam of coal showing an increasing divergence to the point or line of erosion, and we might suppose, unless checked by deductions from previous observations, the two parts to go on diverging indefinitely. There may be exactly similar cases in our Coal-measures which mislead because we obtain a view of only a part of what constituted the original area of the seam. In the *Student's Elements of Geology*, as also in the *Elements*, Sir Charles Lyell brings forward an instance of the supposed coming together of seven widely different coal-seams in Pennsylvania, and he explains, with the aid of a diagram, the method by which such union might be brought about. The explanation is by the subsidence of a part of a marsh and the silting up of the water over the submerged part, thus forming a new surface continuous with the part not submerged. If such submergence is local,—and he speaks of a "lagoon" in a swamp—the division of the main coal would be only a local duplication. But the coming together of widely different seams, each formed originally upon its own water-level, not only involves unequal subsidence, but—what is more difficult of belief—that there was a limited area where all the seams met, which balanced itself at the water's edge, while the adjacent area was sinking and filling up for new marshes, and this repeated many times over. The following is Lyell's statement of the facts as he obtained them in his visit to the United States in 1841, from the late Prof. Rogers: "Between Pottsville and Lehigh Summit Mine seven (of these) seams of coal, at first widely separate, are, in the course of several miles, brought nearer and nearer together by the gradual thinning out of the intervening coarse-grained strata and their accompanying shales, until at length they successively unite and form one mass of coal between forty and fifty feet thick, very pure on the whole, though with a few thin partings of clay." When we come to examine the *Geological Report of Pennsylvania* by the late Prof. H. D. Rogers, we find that these several seams have not been proved by any stratigraphical observations to come together; they have not, by the comparisons of carefully measured sections at different points, been found showing even a convergence, but we have in place of facts only a theoretical conclusion, adopted for the purpose of explaining the unusual thickness of the coal at Summit Hill. I quote all Prof. Rogers says on the subject:

"The only question open to discussion is, whether in an instance like that of the huge mass of the Summit Hill Mines and Panther Creek tunnels, where the bed possesses very unusual thickness, the expansion of its size is caused by the merging into

the principal bed of other adjoining coal-seams through the thinning away of the dividing strata, or is merely a local enlargement of the one coal bed between the same roof and floor, arising from more active deposition at this spot of the vegetable materials which formed it. If we were in possession of any complete sections of the lower coal measures, such as those of the Nesquehoning and Tamaqua coals, illustrative of the condition of things nearer to the Summit Mine than those localities, we might, from such data possibly determine the running together or not of some of those beds to form this great deposit; but no intermediate points have been developed, and the distance of the two localities named, one 4½ miles and the other 5 miles, is too considerable to permit us to institute any close comparison between the individual beds at either of them and that of the Summit. To explain the unusual thickness of the great bed by the coalescing of several large seams of the Nesquehoning group, we must assume, if we take the "main lower coal" and the two next which overlie it, as those which have here come together, that there has occurred a total exhaustion of about 134 feet of included rock, or if we suppose only this "main lower coal" and the double or Rowland's coal to have united, we have still to conceive of the thinning out of 77 feet of sandstone in a range of only 4½ miles. A like difficulty besets us when we consider the thick plates of sandstone and slate which we must assume as having disappeared between the Little Schuylkill and the Summit if we would derive the great bed from the coming together of any two or more of the principal lower seams of that locality. Nevertheless, so much more uniform are the coal beds generally than the mechanically derived sandstones —so much more easy is it when we advert to the respective circumstances under which these two classes of deposition originated, to ascribe a rapid variation of thickness to the wildly-strewn strata of sand and pebbles than to the slowly and gently accumulated layers of vegetation of the ancient carboniferous marshes — that I strongly incline to that view which assumes the apparent alteration of thickness to be due to the thinning out of the arenaceous rocks."

From this language it appears that no facts have been obtained by careful stratigraphical measurements to prove the actual coming together of the different seams of coal, but the union is assumed as, on the whole, the least difficult way of explaining the unusual thickening of the coal at the Summit. This, of course, only the opinion of Prof. Rogers, and is entitled to all the weight which the opinions of so eminent a geologist should receive. It is readily granted that sands are accumulated along shore lines with great unevenness. This depends upon the strength of currents and the quantity of material. Along a shore there are places of comparatively quiet water, where finer sediments, now compressed into shales, are deposited, and we often find these shales alternating with sandstones. In Ohio, on the same horizon, I find sometimes 60 feet of sandrock, and a few miles away 60 feet of shales. The marginal area below the water must be filled up with something, and the unevenness of the resulting bedding of the sandrock or shales is not a matter of consequence, nor is it pertinent to the solution of the problem in hand, viz: the explanation of the unusual thickening of a coal-seam at a given point. The real difficulty is antecedent to the filling in of a submerged area by mechanical sediments, it matters not whether by "sand and pebbles wildly strewn," or by mud gently dropped in more quiet water. How came a part of a marsh, with its coal-making vegetation, 134 feet below its original level, while the remaining part of the marsh maintained such a wonderful statical equilibrium just at the water-line? I do not say that this is impossible, but it is not probable, indeed it is so improbable, that it may not be lightly inferred.

If we accept Prof. Rogers' theory of union of seams to form the great Summit seam, for example, the seams found at Nesquehoning, what are we to conclude becomes of the great aggregated seam as we go towards Tamaqua? The great seam has a geographical limit to its greatness. If its parts separate again, and in their divergence constitute the Tamaqua coal-seams, then we have the interesting fact that a mere bit of an ancient marsh held itself bravely up above water, while all around it the earth kept sinking, interrupted only by those long intervals of repose in which new marshes were formed, upon which grew the vegetation of the successive seams of coal. Such stability in the midst of instability is highly improbable. If, on the other hand, the great Summit seam is not thus divided into diverging parts, but gradually becomes thinner and extends towards Tamaqua, and is represented there by some smaller seam in that direction, then the question very properly arises—why, if a seam of coal may thin out toward Tamaqua, may it not also towards Nesquehoning, and thus render unnecessary the assumption that several distinct and widely separated seams have coalesced?

It is much easier for me to believe that in this famous Pennsylvania case, now made historical by Sir Charles Lyell, the conditions of accumulation of a large mass of vegetable matter were more favorable at that part of the marsh now represented by the Summit Hill coal, than at other portions of the marsh. The conditions of growth might have been more favorable, or there might have been less waste from decomposition, or from mechanical removal. Indeed all these causes might have combined to create the difference in the thickness of the coal. In Ohio I find a seam of coal from 4 to 5 feet thick, and evidently retaining its original and normal thickness, while three miles away the same seam is nearly 13 feet thick. It is as easy for me to believe that a seam might at Nesquehoning be 28 feet thick, as reported, and at the Summit Hill be nearly 50 feet thick, as that a seam in Ohio should, in a less distance, change from 4 to 13 feet.

I am well aware that published sections, taken in a very limited area, sometimes show such a wide variation of intervals between so-called proximate seams of coal that any parallelism seems entirely out of the question. In one case, within the area of a county, where there were five seams of coal in the vertical series, the intervals between each two consecutive seams are given. The published figures show that, in the subsidence, before the second seam from the bottom was formed, the originally horizontal plane of the bottom seam had sunk to depths varying from 34 feet to 87 feet. Before the third seam was formed, the second horizontal plane of coal had sunk irregularly to depths varying from 47 feet to 149 feet. The third plane of coal, in turn, settled down in some places 31 feet, and in others 69 feet, before the fourth seam was laid down; while the plane of the fourth was found to show an irregular subsidence of from 13 feet to 40 feet before the fifth and highest marsh appeared with its luxuriant vegetation. It would be discourteous in me to question the accuracy of the identification of the seams or of the measurements between them. If these figures represent facts, they, with all facts, however stubborn, have their rights. These facts, however, appear to me to have unusual stubbornness. It is barely possible that where we have sands and clay sediments in horizontal alternation, filling the interval between two seams of coal, there might have been a slightly greater compression and condensation of the mass of soft sediments than of the sand, and hence the plane of the coal might show a trifling undulation. I have not, however, observed any such cases.

It is probable that the buried vegetation passed through its changes and became hard and perfect coal in a much shorter time than is generally supposed. In Perry county, I once found near the base of a sandrock, over the Nelsonville or Straitsville seam of coal, a perfect boulder of coal, a flattened disc, nearly four inches in diameter, and two and a half inches deep. It was found about thirteen feet above the seam of coal, there being in the interval a foot of the sandrock and twelve feet of shales. The boulder is a fragment torn from some seam of coal, and rounded by attrition in the moving waters which brought in the sand of the sandstone. The structure of the coal appears to be that of the Straitsville seam. This seam at a location a few miles from the place where the boulder was found, has, over a limited area, been violently torn away by waves or some powerful current of water, and the excavation filled with mud now forming an unstratified mass of clay. As it is hardly possible that the excavation extended downward in deep water to a considerable depth to any of the lower and older seams, we may perhaps infer that the bowlder came from the Straitsville seam at that spot. We have then, the apparent proof that the vegetation became hard and perfect coal after its burial, in time to furnish boulders now found in the coarse sandrock only 13 feet above it. In other words, the time for the accumulation of 12 feet of shales, added to whatever interval there might have been before the incoming of the sand, was long enough for the perfecting of the coal. This time is very indefinite, of course, but measured by stratigraphical accumulation, somewhat after the manner of Prof. Dana's time-ratios, it is geologically very short.

In Wayne county, West Virginia, I found near the bottom of a very coarse sandrock, and separated by about 10 feet of bituminous shale from a thin seam of coal, quite a mass of angular fragments of coal. Some of the fragments were worn the merest trifle, but most were angular, and some were sharply wedge-shaped. It is impossible to believe that fragments of so tender a material could have been subjected to the attrition of the coarse sand with which they were transported, and in which they are now embedded, for any considerable distance. Hence, they were torn from some seam of coal not far away. It is, moreover, unreasonable to suppose, that the cavity of excavation could have extended far down to the lowest and oldest coals, from the fact, stated in the other case, that the work of excavation must have taken place below the surface of the water, the last formed seam being at the time at least 10 or 12 feet below that surface. If the coal came from the seam, first below, it is reasonable to infer that the vegetation of the seam had passed through the processes of bituminization and final solidification, during the interval between the time of the burial by sediments of the coal marsh, and the filling in of 10 or 12 feet of intervening materials. The only other possible explanation of these facts is that some portion of the area of the lower Coal-measures had been raised above its proper place beneath the waters, and either constituted headlands from which the waters of the ocean could tear away the fragments of coal and transport them to their present location, or formed highlands from which rivers might have brought down the coal debris. So far as my observations go, there is not ashadow of proof of any such upheaval during the progress of the formation of our coal-seams, but, on the other hand, all observed facts, militate against such a supposition.

I have observed another class of facts which have interested me much, and which,

perhaps, may have a bearing upon the same point. Over considerable horizontal areas, I sometimes find the coal planed off as if it had already become a solid substance. For example, on Sunday creek, Perry county, I find the thick, or 11 feet seam of coal, (Nelsonville or Straitsville seam), eroded in various places and to varying depths from the top. Sometimes it is planed or ground away to the depth of a foot, sometimes the whole upper bench is gone, and again the erosion has taken away the upper and part of the middle benches. These several benches are always seen in great distinctness in the seam in its normal development, being separated by thin partings of slate. The sandrock fills the space once occupied by the coal. This sandrock rests unconformably upon the eroded edges of the coal. The usual cover of the coal is shales, sometimes 20 feet or more thick, and there is every reason to believe that such shales were first deposited over the coal at the eroded places. At some subsequent time and after the vegetation had become coal, currents of water carried away the soft shales, and perhaps with the aid of moving sand, planed off the upper portion of the coal-seam. It is possible that ice may have been the agent in some cases. This erosion has been done in a smooth and even manner, and there are no traces of that kind of rough work, which the same force would have performed, if the material acted on were a mass of soft and unconsolidated decomposed or decomposing vegetable matter.

In another coal-seam, which I traced for miles in West Virginia, the upper part of the original seam, had almost everywhere been planed off by a force which left over the coal coarse sand, now hardened into a sandrock. In some places, I found the remnants of the original top of the seam with shale over it. It appeared evident, that the sandrock was not the first cover of the coal vegetation. No plants or fragments of trees such as often show themselves in the roof of coal-seams, could anywhere be found in it. In the concavities, in the under surface of the rock, I found the coal which filled them, preserving its horizontal lamination. Apparently the top of the coal-seam after it had become a comparatively solid body, had been planed off, and the sand which covered it adjusted itself to the little inequalities of the surface of the coal. The interval between the time when the vegetable matter was first accumulated, and the time when its first covering of shale was removed and the sands brought in, might have been very great, but relatively to the time of the accumulation of the whole Coal-measures it was very brief.

The buried vegetation of the coal-marshes re-appears after the lapse of long geological ages, in three pretty well marked varieties of coal, viz., the more bituminous or caking, the dry splint, and the cannel, all grouped under the general head of bituminous as distinguished from the metamorphic anthracite. The more bituminous or pitch coal appears to be the natural or normal form which the unaltered vegetation took when buried. Any one familiar with the details of our bituminous coal fields, has often seen in the shales and slates films of this bright resinous coal, where single trunks or branches of *Sigillaria*, *Lepidodendron*, or of large ferns, like *Pecopteris arborescens*, have been buried with an almost perfect exclusion of air. Such films of coal are derived from the bark layers, the interior portion of the tree always, in these cases, disappearing without adding to the quantity of coal. Dr. Dawson regards the mineral charcoal, common in most seams of coal, as the product of the partially decomposed inner bark, and of the more woody portion of the tree, with portions of

other vegetation. In some cases which have fallen under my observation, where there was reason to believe that the tree had been prostrated while a living tree and buried without any previous decomposition, both barks were converted into bright and resinous coal. From this we may, perhaps, infer that if the whole mass of vegetation forming a coal-seam were completely buried, without any previous decomposition, we might expect the whole to be converted into bright coal. Sometimes we find the coal very bright and pitch-like in a considerable portion of the seam, showing scarcely any mineral charcoal, or those laminations of duller color, which are generally supposed to indicate the more decomposed vegetable matter of leaves, fronds and smaller plants. Dr. Dawson thus writes: "I would also observe that, though in the roof shales and other associated beds, it is usually only the cortical layer of trees that appear as compact and bituminous coal, yet I have found specimens which show that, in the coal-seams themselves, true woody tissues have been converted into structureless coal, forming like the coniferous trees converted into jet in more modern formations, thin bands of very pure bituminous material." The probability is that the less the sub-aerial decay, the more perfectly bituminized and structureless becomes the resulting coal. Nothing would be so likely to prevent such decay as immersion in water, and such immersion must play an important part in the formation of the more highly bituminous and caking coals. "In the putrefaction of wood under water or imbedded in aqueous deposits," says Dawson, "a change occurs in which the principal loss consists in carbon and oxygen; and the resulting coaly product contains proportionally more hydrogen than the original wood. This is the condition of the compact bituminous coal. * * * * The mineral charcoal results from sub-aerial decay, the compact coal from sub-aqueous putrefaction more or less modified by heat and exposure to air."

Prof. T. S. Hunt, in the *Canadian Naturalist*, July, 1861, gives the results of the analyses by various chemists, taken chiefly from Bischof's *Chemical Geology*, showing the relative proportions of the elements in wood, peat, coal, asphalt and petroleum. He states that "the nitrogen, which, in most cases, was included with the oxygen in the analysis, has been disregarded, and the oxygen and hydrogen, for the sake of comparison, have been calculated for twenty-four equivalents of carbon."

1.	Vegetable fibre or cellulose	$C_{24}\,H_{20}\,O_{20}$
2.	Wood, mean composition	$C_{24}\,H_{18.4}\,O_{16.4}$
3.	Peat (Vaux)	$C_{24}\,H_{14.4}\,O_{10}$
4.	" (Regnault)	$C_{24}\,H_{14.4}\,O_{9.6}$
5.	Brown coal (Schroetter)	$C_{24}\,H_{14.3}\,O_{10.6}$
6.	" (Woskresensky)	$C_{24}\,H_{13}\,O_{7.6}$
7.	Lignite (Vaux)	$C_{24}\,H_{11.3}\,O_{6.4}$
8.	Lignite passing into mineral resin (Regnault)	$C_{24}\,H_{15}\,O_{3.3}$
9.	Bituminous coal (Regnault)	$C_{24}\,H_{10}\,O_{3.3}$
10.	" "	$C_{24}\,H_{10}\,O_{1.7}$
11.	" "	$C_{24}\,H_{8.4}\,O_{1.2}$
12.	" "	$C_{24}\,H_{8}\,O_{0.9}$
13.	" (Kuehnert and Graeger)	$C_{24}\,H_{7.4}\,O_{1.3}$
14.	" mean composition (Johnston)	$C_{24}\,H_{9}\,O_{2}–O_{4}$
15.	Albert coal (Wetherell)	$C_{24}\,H_{15.9}\,O_{1.6}$

16.	Asphalt, Auvergne	$C_{24} H_{17.7} O_{2.2}$
17.	" Naples	$C_{24} H_{14.6} O_2$
18.	Elastic bitumen, Derbyshire (Johnston)	$C_{24} H_{22} O_{0.3}$
19.	Bitumen of Idria	$C_{24} H_8$
20.	Petroleum and Naptha	$C_{24} H_{24}$

To these analyses add—

Cork	$C_{24} H_{18.2} O_{6.7}$
Lycopodium (Duconi)	$C_{24} H_{19.4} N O_{5.6}$

"It will be seen," writes Prof. Hunt—as quoted by Dr. Dawson in an article in *American Journal of Science* for April, 1871—"from this comparison that, in ultimate composition, Cork and Lycopodium are nearer to Lignite than to woody fibre; and may be converted into coal with far less loss of carbon and hydrogen than the latter. They, in fact, approach closer in composition to resins and fats than to wood, and moreover, like those substances, repel water, with which they are not easily moistened, and thus are able to resist those atmospheric influences which affect the decay of woody tissue."

The finding of spores and spore-cases of Lycopodium in some samples of coal, by Prof. T. H. Huxley, led that distinguished naturalist to conclude that coal was chiefly composed of such material. With Dr. Dawson, I am constrained to doubt this conclusion. That the cortical layers of *Sigillaria*, &c., do form bright resinous coal, without any aid of spores and spore-cases, is seen not only in the shales connected with seams of coal, but often, most distinctly, in the coal itself. The natural inference is that similar laminae of pure coal are of similar origin. The similarity of chemical constitution of modern Cork and spores of Lycopodium, makes it as easy to suppose that the bark of the ancient *Sigillaria*, &c. ,could have formed coal as the spores of the ancient Lycopodium. So far as I have detected spore-cases,—and very large and finely-preserved ones are found in the Straitsville coal,—they are found in the more dull and less pure laminae of the coal.

It is an interesting fact that the beautiful, smooth, vertical planes, which are found, more or less, in all coals, and which, in the same seam always have a uniform direction, and determine the "face" of the coal, are far more abundant in the more resinous or pitch-like varieties. The thin pellicles of bright coal formed when a trunk of *Sigillaria* or other tree is buried in the slates, show these planes in great perfection and profusion. In whatever way the tree may lie, these vertical joints, if joints they may be called, always maintain a constant direction with reference to the points of the compass. In the coal-seams of Southern Ohio, the direction of these planes is proximately east and west, the variation not often being greater than 15° north of west and south of east. I have sometimes found, besides the principal or fundamental planes, a second system forming a uniform angle with the first. In West Virginia, I have found a seam of coal in which these planes held a north-west and south-east direction.

The *splint coal* possesses a less pitch-like character, is more laminated in structure, and generally contains more mineral charcoal. The laminae are harder and tougher and much more difficult to break. The fracture of the coal is sharply ragged and splintery and never vertical, as in the case of the more bituminous and shining varie-

ties. It is evident that the vegetation was more exposed to alternate conditions of moisture and dryness, was thoroughly leached and brought thereby into a condition of fibrous toughness. Such coal compares with the more bituminous and pitch-like coal as fibrous wrought-iron compares with brittle cast-iron. The splint coal separates into large and firm tabular plates, which return to the blow of the hammer a sound almost metallic in character.

Sometimes a seam of coal passes, by almost imperceptible gradations, from the highly bituminous into splint, and in several instances, I have found layers of each alternating in the same seam.

The splint coal is always an open and dry burning coal. It never melts and swells in the fire like the caking variety, and, for this reason, is specially adapted, in the raw state, to the smelting of iron.

Cannel Coal. We should expect that in the swampy flats of the Coal Period, there would be wet places filled with muck or vegetable mud, similar to those we often find in such swamps to-day. In the modern muck-bog, the structure of the vegetation is almost entirely obliterated, and there results a fine soft vegetable mud, which, when dried, forms a dark and almost impalpable powder. We find the proof of the existence of similar locations of vegetable mud in the old coal-producing areas. They were probably not the only wet places;—(for what has already been said of the origin of the more bituminous or pitch-like coals, implies the existence of much water;)—but they were the wet places in which the vegetation became so thoroughly decomposed, that when afterwards buried, compressed and bituminized, it was changed into a hard compact stratum of coal, showing little lustre, often no lamination, and breaking with conchoidal fracture. It is probable that there were vast quantities of vegetable mud formed which did not go to constitute seams of cannel coal, but were floated away by currents, and mingling with mineral sediments settled in the more quiet waters of the shallows, thus forming strata of bituminous slates and shales. Such strata are very common, and, when carefully traced, are generally found to align themselves on the geological horizons of seams of coal. Hence, they serve as excellent guides as we traverse the breaks of continuity in a coal-seam. Every stratum of bituminous shale in our Productive Coal-measures, implies the existence on the same proximate horizon of a coal-marsh, and should always be noted and studied with this fact in mind.

When in the mud forming such bituminous shales, the carbonate of iron has been introduced, we have a stratum of black band ore, unless, as is more often the case, the iron is brought by the force of affinity into nodular masses.

In the water over the accumulating vegetable mud, fishes, mollusks and other forms of life sometimes abounded, and these were entombed in the mud.

In the ooze, the *Stigmaria* almost reveled, penetrating it in almost every direction, and these curious vegetable forms with their spreading rootlets are found in the greatest abundance in cannel coals, all flattened but in exquisite preservation. The existence of so many *Stigmariæ* in the cannel coals, the beds of which often extend for many miles, almost necessitates the conclusion that they grew *in situ*. If the *Stigmaria* is always a true root of the *Sigillaria*, or other tree, as held by Dr. Dawson and others, we must conclude that trees, having these roots attached, grew in the wettest parts of the marsh, which were therefore not open lagoons as some have supposed. But Dr.

Dawson asserts that "*Sigillariæ* grew on the same soils which supported Conifers *Lepidodendra*, *Cordaites* and Ferns, plants which could not have grown in water." He also claims, that most of the under-clays which, so far as I know, universally contain rootlets of *Stigmariæ*, "are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage." These views require us to believe that the *Stigmariæ* could not have grown where they are found in cannel coal, but were floated to their present places as detached roots. If thus floated, we should expect that they would sometimes show local accumulations in drifted heaps. So far as my observations go, they are very evenly distributed over the whole cannel coal areas. Moreover, if detached and floated bodies, and afterwards buried in the accumulating mud, we should naturally expect them also to go to decay and form vegetable muck similar to the surrounding mass.

On the other hand, Lesquereux, Goldenberg and others hold that the true *Stigmaria* was an aquatic plant. Lesquereux thus writes: "It is my belief that the genus *Stigmaria* does not represent tree roots, but floating stems, of which species of the genus *Sigillaria* constitute the flowers or fruit bearing stems." It was, if I understand his views, only under favorable circumstances of a more solid ground for anchorage that these stems produced the stalks, or more properly trunks, by which the fructification was secured. By this theory it is certainly more easy to explain the vast number of *Stigmariæ* found in cannel coals. By it we may, perhaps, also account for the equally great numbers of *Stigmariæ* found in some of the sandrocks of the lower Coal-measures of Ohio, in which *Sigillariæ* are but seldom found. Since we often find *Stigmariæ* in the bituminous coal, the "floating stem" theory would harmonize with the other opinion of Mr. Lesquereux, arrived at after careful study of the marshes and peat bogs of Europe and America, that the coal was formed in similar marshes skirted by the ocean, which would furnish the needed conditions for the growth of such aquatic vegetation as he regards the *Stigmariæ* to be. With the questions of physiological botany involved in the determination of the generic affinities of this strange plant, I have nothing to do. They belong to the palæo-botanists. Schimper, in his recent great work on *Vegetable Palæontology*, after giving the views of different authors, says: "We conclude that, admitting the radical nature of the *Stigmariæ*, we remain very doubtful as to their generic determination, and still more as to their specific reference."

In a seam of coal which I traced for many miles in West Virginia, the coal at one locality is chiefly resinous and bright, and further on passes into a dry splint, and at other points changes into cannel. In one place the vegetable mud, which formed the cannel, was deposited upon a floor of accumulated vegetable matter, which now constitutes a layer of splint. This mass of vegetation had had its day at the surface when that surface was much dryer, but had afterward sunk in the depression of the marsh which formed the muck basin. In another place the cannel coal has over it a layer of splint. In the latter case, the condition of things in the original forming period would resemble that of some of our present marshes, where we find a vegetable ooze below, covered by a quaking surface of growing vegetation including, sometimes, trees of considerable size. If such a marsh were buried under a heavy mass of sedimentary matter and chemical reactions were to take place similar to those of the coal era, we should have something akin to cannel coal below, and above, either a highly bituminous or splint coal, as the case might be.

These general views of the origin of cannel coal I give because they are the results of independent observation on my part. Other geologists have expressed views essentially the same. Mr. Lesquereux has stated that "cannel coal has been formed under water from more decomposed vegetables." Prof. Newberry long since declared that cannel coal was formed from finely macerated vegetable tissues. Dr. Dawson attributes cannel coal to "vegetable mud," and his view is endorsed by Sir Charles Lyell.

Ashes in Coals. The variation in the percentage of ashes in coals is very great. This variation may arise from three causes:

First. The coals may have been formed from different kinds of vegetable tissues which themselves contained varying quantities of ash. It is well known that the different parts of a modern tree, the bark, wood, leaves, &c., give different percentages of ash. Hence coal formed from different parts of the ancient vegetation would doubtless show similar differences. The least ash found in any Ohio coal is 0.77 per cent., and a sample from the same part of the same seam at another location gave 0.85 per cent. These samples contained a very large amount of mineral charcoal, more than I have ever found in any other seam of coal. No examination by the microscope has been made in this case to determine what parts of the plants have formed the charcoal. Dr. Dawson has found in the mineral charcoal of the Nova Scotia coals *bast tissue* from the inner bark of the *Sigillaria* and *Lepidodendron*, especially of the former; *discigerous wood vessels* and *scalariform vessels* of the same and other forms of plants; *vascular bundles of ferns* and *epidermal tissues.* It is possible that the more woody matter of the trees constituted no inconsiderable part of the usual mineral charcoal, and the ash of this would be less than that of coal formed more completely from leaves and from the cortical layers. Samples for analysis, selected with great care, might determine this point.

Second. The quantity of ash would be in proportion to the decay and waste of the vegetation. The ash or inorganic matter of the plant would remain and accumulate, while, in the decay, the organic portions might be entirely dissipated, as is seen in the rotting of wood in our forests at the present day. The more extensive and longer continued the decay, the larger the amount of ash in the final residuum of coal.

Third. The ash is increased by the deposition of sediment from overflows of the coal marsh by muddy waters. This sediment would become intimately mixed with the whole vegetable mass. In some seams of coal we find these sediments so exceedingly fine that they leave a film upon the horizontally accumulating laminæ thinner than the most delicate tissue paper. Sometimes these sediments are so great in quantity as to make the ash very excessive and the coal practically worthless. In the ordinary bituminous coals of Ohio, Prof. Wormley has found the average ash of 88 samples from south-eastern Ohio to be 4.718 per cent., and that of 64 samples from north-eastern Ohio to be 5.120 per cent.

The quantity of ash in cannel coals has a very wide range of variation. This might be expected, for the shallow water standing perhaps a good part of the time in the places where cannel coal was formed, would be an almost constant bearer of sediments, especially if such shallows had openings, wider or narrower, with the ocean on the one side, or with rivers and their bayous on the other, through which such sediments might be introduced. The existence of such openings or channels from the ocean may be assumed from the forms of marine life which entered the inner

water areas where the cannel was formed. Furthermore, these interior shallows being the lowest parts of the marshy area, the waters draining into them from adjacent higher grounds would bring in more or less earthy matter. For these reasons it is hardly to be expected that cannel coal would yield a light ash. The smallest ash I have seen recorded is 2 per cent., while the largest may be 30 or 40, or even more per cent. Many cannel coals are too earthy to be of any value.

I append some analyses of coal ashes.

Analyses of Ash of Coals by Prof. Wormley.

	No. 1.		No. 2.	
	Per cent. of ash.	Per cent. of coal.	Per cent. of ash.	Per cent. of coal.
Silicic acid	49.10	1.645	37.40	0.2880
Iron, sesquioxide	3.68	0.123	9.73	0.0749
Alumina	38.60	1.293	40.77	0.3139
Lime	4.53	0.152	6.27	0.0483
Magnesia	0.16	0.005	1.60	0.0123
Potash and soda	1.10	0.037	1.29	0.0099
Phosphoric acid	2.23	0.075	0.51	0.0039
Sulphuric acid	0.07	0.002	1.99	0.0153
Sulphur, combined	0.14	0.005	0.08	0.0006
Chlorine	Trace.	Trace.	....	....
Total	99.61	3.337	99.64	0.7670

No. 1. Ash from Youghiogheny coal, western Pennsylvania.

No. 2. Ash from J. Sells' coal, Pigeon creek, Jackson county, Ohio.

In No. 2 the ash is very light, being a little less than 0.77 per cent. It contains more iron and sulphuric acid than No. 1, but much less phosphoric acid. In both ashes the largest part is made up of silicic acid and alumina. In both cases, also, there is a notable amount of potash and soda, showing that the ashes possess fertilizing power.

Sulphur. This is a deleterious element found in all coals, not excepting the anthracites which have been subjected to a heating or baking process sufficient to expel the original bituminous portion.

In bituminous coals it exists in different combinations. A part of it is combined with iron to form the bi-sulphide, a part passes off with the volatile hydro-carbons, and a part remains with the fixed carbon of the coke, and a little remains in the ash. A sample of Youghiogheny coal, analyzed by Prof. Wormley, gave of sulphur 0.98 per cent. Of this sulphur (only) 0.097 per cent. was combined with iron as a bi-sulphide; 0.223 per cent. passed off with the volatile matter in coking; 0.653 per cent. was found remaining with the fixed carbon, and 0.007 per cent. remained in the ash. So far as I know, chemists have not yet ascertained the exact nature of the combinations, if any, made by the sulphur with the fixed carbon. Whether the sulphur combines with the carbon of the coke in any known form of sulphide would appear doubtful, from the volatile character of such compounds, which would apparently necessitate their elimination in the process of coking.

From the analysis above given, it is very obvious that the common notion that the sulphur in coals is in combination with iron, is quite a mistaken one. This is further

illustrated by the following table of analyses, by Prof. Wormley, showing the percentage of sulphur in several different coals and that of the iron, and also the proportion of sulphur that could have been combined with the iron.

Sulphur in coal..................	0.57	1.18	0.98	2.00	0.91	0.86	0.57	0.74	4.04
Iron in coal.....................	0.075	0.742	0.086	0.425	0.122	0.052	0.102	0.102	2.05
Sulphur required by iron.	0.086	0.848	0.097	0.486	0.139	0.06	0.116	0.116	2.343

These facts are most interesting and, as will be seen presently, have great practical importance.

While the proportions of sulphur of the bi-sulphide to the total sulphur in different coals are various, it will also be seen that the proportions of that which passes off with the gases in coking to the total, are equally various.

Among Prof. Wormley's analyses, I find the following:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Sulphur in coal................................	0.49	0.93	0.91	0.68	0.57	0.56	0.98
Sulphur left in coke...........................	0.082	0.015	0.007	0.30	0.43	0.46	0.66
Difference, passing off in gases............	0.408	0.915	0.903	0.38	0.14	0.10	0.32

No. 1, coal of lower bench of Straitsville seam.
No. 2, " middle " " "
No. 3, " lower part of seam, J. Sells, Pigeon creek, Jackson county.
No. 4, " upper " " " " " "
No. 5, " Jackson Hill, " Jackson county.
No. 6, " Briar Hill " Youngstown.
No. 7, " Youghiogheny, Pennsylvania.

For gas making, the less sulphur entering the gases, the better, since it must be removed by purification. For the blast furnace, the less sulphur remaining in the coke the better, since it is the sulphur in the coke which is injurious, and not that in the volatile hydro-carbons, which pass off in the top of the furnace stack.

In some cases, however, where the gas carries with it most of the sulphur, the gas may be so superior in illuminating power as to warrant its use, notwithstanding the increased cost of purification. For example, the average sulphur of the whole seam, of 11 feet in thickness, at New Straitsville, is 0.792 per cent. Of this, 0.683 per cent. enters the gas, but the illuminating power being on an average that of 18 candles, the gas is preferred to that made from the Youghiogheny coal, into which there enters but 0.32 per cent. of sulphur, but has an illuminating power of only 14 candles.

In the evolving of gas from coals a part of the volatile combustible matter condenses into tarry matter, and has to be deducted in our calculations from the total gas, the remainder being the fixed or permanent gas. The difference between the whole volatile combustible product and the permanent gaseous matter is often very considerable, and this difference varies in different coals. Prof. Wormley gives the following illus-

tration: "A coal which contained only 27.70 per cent. of volatile combustible matter evolved 3.32 cubic feet of fixed gas per pound, whilst another, which contained 38.80 per cent. of volatile combustible matter, evolved only 3.03 cubic feet per pound." Of 14 samples tested, the average volatile combustible matter was 33.54 per cent., and that of the fixed gas in cubic feet per pound of coal was 3.306. Gas-works practically obtain more gas per pound than the chemists, doubtless, through a redistillation of tarry matters and their conversion into permanent gas. Prof. Wormley also suggests that at such works "the measurement is taken at a higher temperature; a difference of five degrees changing the volume of gas about one per cent." From "a fair average sample of Youghiogheny coal," Prof. W. obtains "only about $3\frac{1}{2}$ cubic feet of gas per pound, whereas, in the ordinary manufacture of illuminating gas, this coal, as is well known, yields about 4 cubic feet per pound of coal."

The sulphur in coals is derived from two sources, viz: from the vegetation itself and from the water of the ocean. Bischof states that "the ash of beech wood contains as much sulphuric acid and peroxide of iron as would suffice to form iron pyrites amounting to $\frac{1}{48077}$ of the weight of the wood. The peroxide of iron would yield 23 times as much pyrites, if sulphates were brought in contact with it from outwards. Fir wood can give rise to the formation of ten times as much iron pyrites as beech wood."

The large amount of carbonaceous matter of the coal vegetation acting upon the alkaline and earthy sulphates in the sea water would, with the aid of proto-carbonate of iron, form more or less pyrites, and Bischof asserts that it is actually formed in this way. He, however, limits the action upon sulphates, as far as it goes on in the sea, to the decomposition of sulphate of lime. But these chemical reactions only explain so much of the sulphur as is combined with iron as pyrites or bi-sulphide. It is barely possible that so large a body of decomposing carbonaceous matter might set free more sulphuric acid from the sulphates than there was iron to combine with, and the excess, probably losing its oxygen, went to form new combinations with the organic matter of the decomposing vegetation.

I can, in conclusion, notice only one or two matters of practical importance in the use of bituminous coals. The vast quantity of excellent iron ore in our land, with a corresponding amount of excellent fuel for smelting it, points to this country as one destined to become the leading nation in iron manufactures. In this industry our bituminous coals are already beginning to play an important part.

The pre-requisites for a good furnace coal are, if we use the raw or uncoked coal, a dry or open-burning quality, little sulphur, a reasonably small ash, sufficient fixed carbon and firmness of coke. If coke, and not raw coal, be used, it should be firm and capable of resisting pressure, and contain as small percentages of sulphur and ash as possible. Sulphur in coal is a prime difficulty, but this is becoming better and better understood by iron manufacturers. Of late years, attempts have been made, with greater or less success, to separate the sulphur from coal by a somewhat expensive mechanical process, viz., by crushing the coal and floating off by water the lighter and purer portions, which are saved and afterward converted into coke. The rest, composed of the coal charged heavily with bi-sulphide of iron, and of slate, is thrown away. When, however, the sulphur is not combined with iron as a bi-sulphide, but is in other combinations, as has already been shown, this mechanical process must fail. And even when, as is often the case, the bi-sulphide is disseminated evenly through the whole mass of the coal, and is not in a segregated condition in the form

of laminæ, discs, &c., there will also be a failure in the separation. The sulpur may be combined with the lightest and apparently purest portion of the coal, if quality is to be determined by specific gravity.

For illustration, I give the analysis of a coal which appeared in every way promising, and contained no visible bi-sulphide of iron. There was found in it, by Prof. Wormley, 0.39 per cent. of iron. This iron would require 0.445 per cent. of sulphur to form the usual bi-sulphide. Besides this amount, there remained in the coal 2.885 per cent. of sulphur. This large amount of sulphur could not be removed by any washing process, since it is disseminated through the whole mass of the coal. If the purification of the coal is, therefore, to be attempted by discriminating, by a mechanical process, the relative specific gravities, the method will only be successful where the sulphur is in the form of bi-sulphide of iron, and this is in a segregated form.

Another important point to be determined in the use of bituminous coal for iron-making is the physical character of the coke. If raw coal is used, it is speedily converted into coke in the top of the furnace, and descends as such to the bottom, where it is consumed and the chief heat produced. While in the bottom there rests upon it, and upon the other materials which have descended with it, the burden of the whole vertical column of the contents of the furnace directly above. The coke, therefore, should be firm and solid to hold up this superincumbent mass. If it is, on the other hand, tender and crushes under the weight, it becomes compacted together, the blast does not penetrate it, and a slow and imperfect combustion is the result. From such impeded combustion many and great evils arise, which are familiar to all intelligent iron-masters. To this cause, more than to any other, is to be attributed the "bad working" of so many furnaces using tender fuels. The strongest cokes are made from the more highly bituminous and caking coals, such as melt and swell when heated, and after the bituminous gases are driven off, leave a hard, cinder-like mass, which has an almost metallic lustre and a metallic ring when struck. Such coke, either cold or hot, is broken with difficulty, and will resist great pressure without crushing. The best English coke of this type is made from the North Durham coal. It is the strength and firmness of this coke that renders the very high furnaces of the Cleveland Iron District possible. The coke made from a similar highly cementing coal at Connellsville, Pa., has a somewhat similar firm and obdurate quality. All cokes made from the soft and caking coals have a tendency to be more or less firm, from the fact that such coals soften and melt when heated. The best coke comes from the most thorough fusion of the coal. On the other hand, the open and dry-burning coals show a very different behavior in the fire. They do not melt and swell, and, consequently, change but slightly their original form. A block of such coal parts with its bituminous gases through cracks which more generally open along the planes of lamination. The resulting coke is darker in color, less coherent and firm, and less able to sustain the pressure at the bottom of the furnace stack. Of course some of the cokes of each class are much firmer than others. Often iron-masters using dry coals in the raw state, and finding that they do not obtain sufficient heat, resort to the use of a certain proportion of firm coke. The difficulty is not, I think, in the want of heating power in the raw coal, for its coke may have quite as much fixed carbon as the other coke used, but in the simple fact that, in the first instance the fire is partially smothered by the compacted condition of the fuel, while, in the other case, the weaker coke of the raw coal is reinforced by the stronger, and thus the whole mass of the fuel is kept in better condition to be permeated by the blast.

There are very great advantages in large and high furnaces, as has been practically shown in the Cleveland Iron District, England, and theoretically by I. Lowthian Bell in his masterly papers in the *Journal of the Iron and Steel Institute.*

In Ohio we have a vast supply of dry burning bituminous coals, more or less splint in character, of great purity and excellence, which can be obtained very cheaply. These coals must largely be used for iron-making and will be; but the character of each kind of coal must be carefully ascertained, and the nature of the cokes must also be carefully studied. No two coals are exactly alike, and it is not wise to copy blindly the forms of foreign furnaces, which have succeeded under entirely different circumstances and conditions.

REPORT ON THE THIRD GEOLOGICAL DISTRICT.

GEOLOGY OF THE CINCINNATI GROUP.

HAMILTON, CLERMONT, WARREN AND BUTLER COUNTIES

BY EDWARD ORTON.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—I herewith transmit my contribution to the First Volume of the Final Report of the Ohio Geological Survey. It comprises a discussion of the General Geology of the Cincinnati Group—and in connection with this, reports upon the four counties of Hamilton, Clermont, Warren and Butler—in which this formation is best shown. A report on the Geology of Clarke county is also appended.

If the manuscript bids fair to cover more ground than has been assigned to my district in the forthcoming volume, I should select for omission the reports on Warren and Butler counties—one or both—rather than any of the other material submitted.

I take this opportunity to say that the present reports embody in part the results of the very faithful and competent labors of Messrs. F. C. Hill and R. B. Warder, who have been employed as assistants on the survey of the district herein described.

In treating of the Geology of the Cincinnati group, I have freely availed myself of all the sources of information open to me, but I wish especially to acknowledge the obligations I am under to those gentlemen in and around Cincinnati, who have given particular attention to the geology of the very interesting formation that derives its name from their city. From many of them I have received very valuable information relating to the work in hand, but a few of them have rendered such special and important aid that I should do wrong if I omitted from this report the particular mention of their names. I refer to Messrs. U. P. James, C. B. Dyer, S. F. Miller and S. T. Carley.

To Messrs. John Howell and John Snyder, of Clarke county, and to Mr. L. C. Moore, of Clermont county, I am also greatly indebted for assistance in working out the details of the local geology of these districts.

I remain, with great respect,

Very truly yours,

EDWARD ORTON.

YELLOW SPRINGS, OHIO, October 1st, 1872.

CHAPTER XIII.

THE CINCINNATI GROUP, OR BLUE LIMESTONE FORMATION.

HAMILTON, CLERMONT, WARREN AND BUTLER COUNTIES.

The bedded rocks of several of the south-western counties of Ohio, must be referred in whole or in part to a single geological formation, viz: the Cincinnati Group. Hamilton, Clermont and Brown counties contain no other rock formation within their limits. Warren and Butler hold, in addition, outliers of cliff limestone, but of inconsiderable extent. Adams, Highland, Clinton, Green, Clarke, Miami, Montgomery and Preble, all give exposures of the Cincinnati Group in their valleys—some of them of quite ample area, and others that are only to be seen in the thread-like channels of their southernmost water-courses.

In those portions of the Ohio Geological Reports of 1869 and 1870, that pertain to the south-western portion of the State, reference is repeatedly made to the structure and history of the Cincinnati Group, as exhibited in the counties there treated of, but the main discussion of this important formation has been reserved until those counties should be studied which give the most extended and most numerous sections of it. The four counties named at the head of this report, viz: Hamilton, Clermont, Warren and Butler, certainly include the whole vertical extent of the Cincinnati Group as it occurs in Ohio—and there are very few peculiarities in any portion of its horizontal range that are not well exhibited within their area. Brown county contains as interesting and extensive a section of this formation as any one of those here named, and might well enough be treated in the same connection, but for the sake of convenience it was otherwise assigned, and a report on its geology, written by another hand, will be found in a succeeding volume.

In treating of the geology of the counties above named, an account will first be given of the great formation which is common to them all, after which the peculiar geological features of each county will be separately discussed. The geology of the Cincinnati Group will be treated under the following heads:

I.—Geological Position and Equivalents.
II.—Divisions of the Series.
III.—Lithological Characters and Composition.
IV.—Paleontology and General History.

I.—Geological Position and Equivalents of the Cincinnati Group.

The approximate place in the general geological scale of the strata exposed in the hills of Cincinnati, has long been known. For the last thirty years, at least, they have been referred to the later divisions of Lower Silurian time. The names by which the sub-divisions of the Silurian and Devonian rocks of North America have generally been designated, are those that were given by the geologists of the New York Survey, and which were authoritatively published by them in their reports of 1842. There are several excellent reasons why the succession of these older rocks in New York should be assumed as the standard for the country at large. In the first place, some standard must be adopted, and the New York names have the great advantage of priority. In the second place, the older fossiliferous strata of the continent are nowhere shown to better advantage than in New York, and nowhere else is there a more extended and detailed series. In the third place, and finally, the divisions adopted in New York have been rendered available for comparison by the description and figures of the fossils which they contain and by which they are characterized, in the splendid volumes of Paleontology, published by this State; and thus an acquaintance with these divisions is made imperative upon all who would study the older fossiliferous rocks of America.

In accordance with this usage, the rocks exposed at Cincinnati have been recognized as belonging to the Hudson, or Hudson River Group, of the New York geologists, and of the general geological scale of the country. It has been, however, found that this designation was unfortunately chosen, as some of the localities along the Hudson river, from which the formation received its name, have been proved to belong to a very different horizon from that which was meant to be designated, viz: the uppermost period of the Lower Silurian. Accordingly it has been

proposed to drop this designation altogether, at least in its application to strata west of the Alleghanies, and to substitute for it the name Cincinnati Group—making this term co-extensive with the former. Worthen and Meek, in a paper published by the Philadelphia Academy of Sciences in August, 1865, distinctly proposed this change, and in their reports upon the geology of Illinois, since published, the change is adopted and justified.

There are certainly many grounds on which the latter designation is to be preferred. Its advantages are that it directs the mind to a definite locality, where there is a very extensive development and admirable disclosure of the rocks belonging to this group, and from which abundant and well preserved fossils have been carried to every part of the world in which geology is studied.

The name "Cincinnati Group" is accordingly used in this report as the equivalent of the Hudson River Group of the New York Reports, and of the Hudson Period of Dana. Its boundaries, therefore, are the Trenton Limestone below and the Upper Silurian formations above. The latter boundary is very precise and definite, as was shown in the reports of 1869 and 1870 on the geology of Montgomery and Highland counties. The lower boundary has not yet been definitely fixed. Enough is known, however, to make it certain that it is not found among the surface rocks of Ohio. There are beds in the vicinity of Frankfort, Kentucky, that are pronounced by Meek to be unmistakably of Trenton age, as determined by the presence of certain fossils.

At some intermediate point, then, between Frankfort and Cincinnati, the base of the Cincinnati Group is to be looked for.

The Hudson River Group of New York is composed of at least two well-defined members, separable on lithological grounds, as well as by the fossils they contain—viz., the Utica Slate, and the Hudson River sandstone, or the Gray Sandstone of Oswego. There are no constant differences in lithological characteristics upon which divisions can be established in the Cincinnati Group as it is shown in the Ohio valley, and there is a blending of fossils here through the whole series—Trenton, Utica and Hudson forms being to a considerable degree intermingled—that makes it difficult to establish the boundaries of any sub-divisions. It will, however, be shown to be probable that the lowermost beds of Cincinnati are the proper equivalent of the Utica Slate; in other words, that these shales and limestones were growing here, while the black Utica shales were in process of deposition in eastern New York.

II. Divisions of the Series.

There are certain divisions, however, of this system possible which involve no doubtful questions like those to which reference has just been made, and which serve to facilitate the study of the group. These divisions are founded upon the fact that certain portions only of the series occur in the typical locality of the formation, viz., the Cincinnati hills, while in other localities, divisions both below and above these beds are found. The lowest beds of the Group, or in other words, the lowest rocks of Ohio, are not found at low water mark of the Ohio at Cincinnati, as is generally believed, but from the fact that the main axis of the Cincinnati uplift lies to the eastward of the city, and that the dip in the vicinity of Cincinnati is mainly northward—points which will be dwelt upon and illustrated in a subsequent part of this report—it results that the river quarries in the central portions of Clermont county, which lie a dozen miles south of Cincinnati, disclose rocks that underlie by at least 50 feet the lowest beds at Cincinnati.

The locality at which these lowest rocks of the State present the best exposures and clearest section, is Point Pleasant, and this division can accordingly be named the *Point Pleasant beds.* Its boundaries have been already assigned by implication; these beds beginning at low water mark at Cincinnati, and descending until they include the lowest rocks exposed in the State. It is not easy to determine with exactness the upper boundary above mentioned at Point Pleasant, as no facts can be found in either lithological or fossil characters that serve to identify any particular layer as the bottom layer at Cincinnati, but judging from such indications as both lithology and fossils furnish, it is safe to say that the Point Pleasant beds have at least the thickness already assigned to them, viz., 50 feet.

The *Cincinnati beds* proper, come next in order, having for their inferior limit low water of the Ohio, and for an upper boundary the highest stratum found in the Cincinnati hills. The greatest elevation above low water in the immediate vicinity of Cincinnati is given by the City Engineer as 465 feet. Abating 15 feet for the drift covering of the surface, we can certainly find 450 feet of bedded rock in this division, almost every foot of which lies open to study within the city limits. The only stratum, however, that admits of easy identification, lies at an elevation of 425 feet above the river, and this is accordingly assumed as the upper limit of this division.

Upon differences in lithological character, with which also changes in fossil contents ally themselves, a sub-division of the Cincinnati beds is

possible into three groups, which may be named, respectively, in ascending order, the *River Quarry beds*, the *Middle Shales* and the *Hill Quarry beds*. The first of these sub-divisions has a thickness of 50 feet, the second of 250 feet, and the third of 150 feet.

Above the highest stratum of the Cincinnati hills and the lowermost beds of the Upper Silurian age, 300 feet of rock intervene, that belong unmistakably to the same formation, being connected with it by identity in lithological character and by a large number of common fossils. These upper beds are nowhere found within twenty miles of Cincinnati, and yet there has never been the slightest hesitation in referring them to the same series to which the rocks there exhibited belong.

There are very many points in southwestern Ohio in which admirable exposures of this portion of the series can be found. Among those that are best known, from the fact that large numbers of fossils have been collected at these localities, are Oxford and Lebanon. Madison and Richmond, Indiana, are equally well known and equally remarkable for the abundance and perfection of the fossils that they furnish. This division occupies the northern half of Butler county, the northern and eastern half of Warren, the northern edge of Brown county, and makes up the whole of the Blue Limestone formation in Preble, Montgomery, Miami, Clarke, Greene, Clinton, Highland and Adams counties. In the valley of the Great Miami it extends from the hills around Hamilton northward to Troy; and in the Little Miami valley from the highest ground near Morrow to Goe's station, above Xenia. The vicinity of Dayton gives unsurpassed facilities for studying the upper limits of this group. Any of the localities named could be made to furnish an unambiguous and appropriate name for this section of the Cincinnati Group. Geologists would at once recognize the horizon designated if these beds were known as the Richmond, Madison, Oxford, Dayton or Lebanon beds. The last of these names has been selected for the division now under consideration for the following reasons. The strata that form the summit of the Cincinnati hills are found in the immediate vicinity of Lebanon, and the series can be traced from this point very directly to the Upper Silurian rocks, an advantage which Oxford does not share. In fact, there are two sections in the vicinity of Lebanon that complete the series of the Cincinnati Group more concisely than any others known in the range of these rocks within the limits of Ohio.

One of these is five miles east of Lebanon, on the Lebanon and Wilmington road. Beginning where this road intersects the Little Miami railroad, in the river valley, the beds outcropping just above the railroad track are found to belong to the same horizon with the highest beds at Cincinnati. In following the road due east for three miles, we come

upon an outlier of Clinton limestone, the lowest layer of which is 320 feet above the track of the railroad. The junction of the two formations is most distinctly and beautifully shown at this point.

The other section named has even narrower limits. It is found five miles to the north-east of Lebanon. Starting from the river valley again, just opposite the Cæsar's Creek railroad bridge, a water course that enters the river here can be followed in a nearly direct line to another outlier of Clinton limestone, which forms what is known as Morris's Hill. This section is especially interesting and valuable, because the distance traversed is so small, not more than two miles intervening between the points named, and also because almost every foot of the included rock is shown in the bed of the stream or in the minor gorges that are tributary to it. The thickness of that part of the series that lies outside of and above Cincinnati, was determined from careful measurements of this section. No account was made, however, of dip, which is very small in amount in all this portion of the State, and affects this section less than it would one running in a different direction, as, for example, north and south.

The divisions already named are established upon the fact of their occurrence at certain localities, as will be remembered, their presence in the typical section of the group at Cincinnati, or their absence from that section, being made the ground of separation. There are, however, facts in the distribution of the fossils which the rocks contain, that ally themselves with these divisions, and to the establishment of which, indeed, they are necessary. We are able, for instance, to correlate the beds found at various distances from the city, with the beds of the Cincinnati hills, on the evidence furnished by fossils, and on this alone. These facts will be seen in better light when the fossil contents of the rocks come to be noted.

The subordinate groups into which it has been found convenient to divide the Cincinnati beds proper, also involve the fossil contents of the rocks, as well as their lithological characteristics, so that at this point it is unnecessary to do more than name them, as has already been done.

The names assigned, it will be remembered, to the three divisions recognized here, are in ascending order:

The River Quarry beds;
The Middle, or Eden shales;
The Hill Quarry beds.

No explanation is necessary of the first and last of these names. To the intervening division a name can properly be assigned, derived from the name of the park on the eastern side of the city, in the grading of

which so great a display of this division is made. This division can, therefore, be styled the Eden shales, from Eden Park.

The general statements that have been made under this head may be summed up in tabular form, thus:

Cincinnati Group of South-western Ohio.	Lebanon beds	293 ft.		
	Cincinnati beds, proper	425 ft.	Hill Quarry beds	125 ft.
			Eden shales	250 ft.
			River Quarry beds	50 ft.
	Pt. Pleasant beds	50 ft.		
		768 ft.		
	In round numbers from 775 ft. to 800 ft.			

III.—Lithological Character and Composition of the Cincinnati Group.

This whole series is composed of alternating beds of limestone and shale. The shale is more commonly known under the name of *blue clay*, and this designation is not inappropriate. It is sometimes styled *marl* or *marlite*, and the use of the latter designation is also justified by its composition. The most objectionable term by which it is characterized is *soapstone*, as this name is preoccupied by a metamorphic magnesian silicate.

The limestone of the series may, in general terms, be described as an even-bedded, firm, durable, semi-crystalline limestone, crowded for the most part with fossils through its whole extent, and often bearing upon its surface the impressions of these fossils. Its color is not uniform, as the designation by which the whole series is familiarly known, viz., *blue limestone*, would seem to imply. The prevailing color, however, may be said to be a grayish blue, chiefly due to the presence of protoxide of iron, which, upon exposure, is converted into a higher oxide. The weathered surfaces generally show yellowish or light gray shades, that are in marked contrast with the fresh fracture. Drab colored courses occasionally alternate with the blue.

The limestone varies in all these respects somewhat, however, in its different divisions. The Point Pleasant beds, and the lower courses of the Cincinnati division, deviate most widely from the description already given. They are lighter in color than the upper courses, and, in some instances, are slaty in structure, while in others they have a tendency to assume lenticular forms of concretionary origin, sometimes to such an extent as to destroy their value as building rock. The layers are also

exceptionally heavy, attaining a thickness of 16 or 18 inches, and are often so free from fossils as to afford no indication of the kinds of life from which they were derived.

A few feet above low water, at Cincinnati, a very firm and compact stone comes in, that is found in occasional courses for 50 or 75 feet. It is composed, as its weathered surfaces show, almost entirely of crinoidal columns, mostly of small size, and mainly referable to species of *Heterocrinus*. The courses vary in thickness from an inch to a foot. The lighter layers ring like pot-metal under the blows of a hammer.

Ascending in the series, the limestone layers are very generally fossiliferous, and are rarely homogeneous in structure, being disfigured, to a greater or less degree, by chambers of shale or limestone mud, from some of which cavities, certainly, fossils have been dissolved. The thickness of the courses varies generally between the limits indicated above, but a large proportion of the stone ranges between 4 inches and 8 inches. Now and then, however, a layer attains a thickness of 20 inches, or even 2 feet. Near the upper limits of the formation the layers are thinner and less even than below, affording what quarrymen call a *shelly* stone.

The composition of the limestones from the upper half of the group is quite nearly uniform, averaging about 90 per cent. of carbonate of lime, but as we descend in the series the limestones grow more silicious. A few analyses are here introduced, which serve to illustrate these facts. These analyses were made, with a single exception, by Dr. Wormley, for the survey:

No. 1. Limestone from Lebanon beds, Waynesville.
No. 2. " " middle division, Cincinnati.
No. 3. " " river quarries, Cincinnati.
No. 4. " " New Richmond.
No. 5. " " Point Pleasant.
No. 6. Drillings from 500 feet below low water at Cincinnati.

	1.	2.	3.	4.	5.	6.
Silicious matter	....	....	23.48	10.80	12.00	37.10
Alumina and iron	....	....	3.40	1.40	7.00	1.80
Carbonate of lime	91.50	....	71.30	86.60	79.30	57.10
Carbonate of magnesia	5.06	....	1.89	1.13	0.91	4.01
	96.56	....	100.07	99.93	99.21	100.01

The shales, clays or marlites, which with the limestones make up the Cincinnati Group, must next be characterized. They constitute a large part of the system, certainly four-fifths of it in the two lower divisions, and probably not less than three-fifths of its whole extent. The propor-

tions of limestone and shale do not appear altogether constant, it is to be observed, at the same horizon, a larger amount of stone being found at one point than at others.

The shales—as implied in one of the names by which they are known —*blue clay*—are generally blue in color, but the shade is lighter than in the limestone. In addition to the blue shales, however, drab-colored clays appear in the series at various points. As the blue shales weather into drab by the higher oxidation of the iron they contain, the conclusion is frequently drawn that the last named variety marks merely a weathered stage of the former. But aside from the impossibility of explaining the facts as they occur on this hypothesis, analysis disproves it, and shows that the differences in color are connected with essential differences in the composition of the belts to which they belong. A few analyses made for the survey by Dr. Wormley, are here appended. They are arranged in the order of the strata to which they belong.

1. Fossiliferous shale, Waynesville.
2. Blue Shale, Brighton Hill, Cincinnati.
3. Blue Shale, Sycamore St. Hill, "
4. Drab Shale, " " "
5. Fossiliferous Shale, " " "
6. Shale from River Quarries, Covington, Ky.
7. " " " " "

	1.	2.	3.	4.	5.	6.	7.
Silicious matter	69.60	70.40	81.50	56.80	67.40	43.20	72.80
Alumina and iron	10.24	9.00	9.00	25.80	7.80	5.00	6.80
Carbonate of lime	12.55	14.40	3.40	7.10	18.30	47.40	13.10
Carbonate of magnesia	1.91	5.75	2.64	4.45	3.78	3.47	4.62
Potash and soda	5.40	....	....	....	....	....	....
Phosphoric acid	0.16	....	....	....	....	....	....
Water combined	....	....	3.20	4.70	....	2.50	....
Total	99.86	99.55	99.74	98.85	99.78	99.07	99.32

Most of the shales slake promptly on exposure to the air, and furnish the materials of a fertile soil; but there are other portions included under this general division which harden as the quarry water escapes, and become an enduring stone if protected from the action of frost.

The shales are sometimes quite heavily charged with fossils, which generally have a firmer structure than the material that encloses them, so that the fossils, often in an admirable state of preservation, remain behind after the shales have melted away. All of the groups of animals

that are represented in the limestones are found also in the shales, but from the unequal numbers that are represented here to-day, it seems evident that some sorts were able to adapt themselves to the conditions which shaly deposits imply much more easily than others.

The proportions of limestone and shale in the series have been already spoken of in a general way, but it will be profitable to give additional statements on this point. In the river quarry beds—the lowermost portion of the Cincinnati beds proper—there are about four feet of shale to one foot of limestone, but the shales increase in force as we ascend in the series, until at about one hundred feet above low water the proportion is more than twice as great. For the two hundred feet next succeeding, that have been styled the *Eden Shales* or *Middle Shales*, there is seldom more than one foot of stone in ten feet of ascent. The amount of waste is so large, therefore, that quarries cannot be profitably worked in this whole division. The third portion of the series—the Hill Quarries—have for their lower limits the beds in which the solid rock has risen again to as high a proportion as one foot in five or six feet of ascent. From this point upward to the completion of the group, there is no such predominance of shale as is found below, though in the lower parts of the Lebanon beds, shales still constitute more than one-half of the whole thickness.

It will be seen from one of the analyses already given, that a notable quantity of alkalies and phosphates, sometimes at least, occurs in the composition of the shales. It is upon these substances that the fertility of soils in great measure depends; and as they are in this case properly distributed through the sand and clay that make the bulk of the shale, it is in no way surprising to find very fruitful soils forming from the weathering of these beds. The most noteworthy fact in this connection is the rapidity with which they are converted into soils. Most of the rocky strata of the State require a long course of progressive improvement before they can be justly termed soils. Their elements are slowly oxydized and disintegrated, and vegetable matter is slowly added. The exposure of a single season, however, suffices to cover the Cincinnati shales with a varied vegetation. All of our ordinary forest trees, when opportunity is furnished for the distribution of their seeds, establish themselves promptly upon the shales. The black locust seems especially well adapted to such stations. There is no use to which the steep slopes of the Cincinnati hills can be turned that would subserve as many interests as planting them with black locust would do. Of the plants that are first to come in to occupy the newly exposed shales of the Hill Quarries,

the following, most of them troublesome weeds, may be named as very common.

Poa compressa (Flat-stemmed blue grass.)
Phleum pratense (Herd's grass.)
Dipsacus sylvestris (Teasel.)
Cirsium lanceolatum (Thistle.)
Lappa major (Burdock.)
Rumex crispus (Yellow dock.)
Asclepias cornuti (Milk weed.)

Dr. Locke called attention to a peculiar feature of the Blue Limestone beds, viz: a waved structure of the solid limestone, somewhat analogous in form to the wave-lines and ripple-marks of the higher series of the State. This peculiar structure was noticed by him in the upper beds of the formation, but it is an even more striking characteristic of the rock in its lower beds, as shown in the river quarries of Cincinnati, or in the lowermost 100 feet that are there exposed.

The rocks exhibiting this structure at the point named, are the most compact beds of the fossiliferous limestone. The bottom of the waved layer is generally even, and beneath it is always found an even bed of shale. Its upper surface is diversified, as its name suggests, with ridges and furrows. The interval between the ridges varies, but in many instances it is about four feet. The greatest thickness of the ridge is six or seven inches, while the stone is reduced to one or two inches at the bottom of the furrow, and sometimes it entirely disappears. The waved layers are overlain by shale in every instance. They are often continuous for a considerable extent, and in such cases the axes of the ridges and furrows have a uniform direction. This direction is a little south of east in the vicinity of Cincinnati, but in traversing the series these axes are found to bear in various directions.

Dr. Locke's explanation of these facts, involving a fluid state of the carbonate of lime and sheets of shale falling in "vertical strata" through deep seas, seems entirely inadmissible.

The only other explanation thus far proffered is that suggested by the name, viz: that the floor of the Cincinnati sea was acted on from time to time by waves or similar movements of the ocean waters. In opposition to this view, it may be said: 1st, That there are many reasons for believing that the Cincinnati rocks grew upon the floor of a deep sea, far below the action of surface waves; and 2d, That the fact of the limestone layers alone being thus shaped, is sufficient to set aside the explanation. If these inequalities of surface are due to wave action of any

sort, it is impossible to see why the action should be limited entirely to the firmest limestone beds of the series, while the soft shales, which could so easily register any movement of the waters, never exhibit the slightest indications of such agencies.

While both of these modes of accounting for the facts are rejected as entirely unsatisfactory, nothing in the way of explanation will be offered here, but the suggestion that the facts seem to point to concretionary action, as the force to which we must look.

The economical products of the Cincinnati Group are limited to building stone, lime, brick and pottery clays and cement, and of these none but the first two have, at present, any great importance. The series yields everywhere abundant supplies of stone, suitable in every respect for building purposes. The advantages that the city of Cincinnati reaps from the quarries that surround it, is immense. While Blue Limestone has been used as a building stone from the first settlement of the country, it has hitherto enjoyed the reputation of being serviceable rather than beautiful, but within the last few years it has been so treated by combination with other building-stones, as to produce very fine architectural effects. Numerous exhibitions of this skillful use of the Blue Limestone can be seen in the recent buildings of the city and suburbs of Cincinnati. No better example can be named than that furnished by St. Paul's (Methodist) Church on Seventh street.

The analysis of the stone already given shows it to contain 90 or more per cent. of carbonate of lime. From this it will be concluded that it can be burned into a lime of a good degree of purity and strength. When water-washed pebbles from gravel banks or river beds are used, the product is excellent, but the quarry stone always carries with it so much of the interstratified shale as to darken the lime and so reduce its value for plastering For this last use, the mild and white magnesian limes derived from the Upper Silurian formations that surround Cincinnati, are the only varieties that are at present approved. The native supply can, however, be furnished much cheaper—at but little more than half the cost, indeed, of Springfield lime—and as it makes a strong cement, the shales that adhere to the stone possibly adding a hydraulic quality, it is generally used in laying foundations of all sorts.

The shales are sometimes resorted to for the manufacture of brick, tile and pottery ware. The instances are, however, rare, and are confined to the uppermost beds of the system. The products resulting were, in the few instances noted, unusually fine, the clay working very smoothly and burning into cream colored ware of great strength and excellence.

The occurrence of concretions in the shales of the Point Pleasant beds

and in the lowest strata of the division found at Cincinnati, has already been noticed. The analysis of a specimen from the River Quarries at Cincinnati, gives the following result:

Silicious matter	14.00
Alumina and iron	2.60
Carbonate of lime	80.20
Carbonate of magnesia	3.32
Total	100.12

Such a composition suggests hydraulic cement, and the specimen analyzed was found to possess a high degree of hydraulic energy. The supply of these concretions depends upon the extent of the quarrying, but at the present rate several hundred tons are thrown out each year; and as the concretions prove nearly enough uniform in composition, they can certainly be turned to good economical account in the manufacture of a fine quality of cement. The famous Roman cement of England is obtained from similar concretions, which are generally gathered on the shore after storms and high tides, though sometimes obtained by digging. All of the river quarries from Point Pleasant to Lawrenceburg, Indiana, yield these concretions—the lowermost beds of all most abundantly.

The composition of these concretions is still further shown in the appended analyses (Wormley):

No. 1. Concretion, river quarries, Covington, Ky.
No. 2. " " "
No. 3. " " "
No. 4. " " "
No. 5. " " Point Pleasant.
No. 6. " " "

	1.	2.	3.	4.	5.	6.
Silicious matter	42.40	23.10	21.40	28.70	18.00	12.40
Alumina and iron	6.40	2.60	2.20	2.40	2.60	3.00
Carbonate of lime	46.40	71.60	73.00	65.30	76.40	73.20
Carbonate of magnesia	4.40	2.51	2.72	2.99	2.27	10.44
Total	99.60	99.81	99.32	99.39	99.27	99.04

To these facts it may be added that the limestones enclosing the concretions are silicious enough in composition to transfer them to the list of cements. The composition of two specimens of this character is shown in the analyses given on a preceding page.

IV.—Paleontology and General History of the Cincinnati Group.

The most important division of the subject remains to be discussed. A somewhat elementary treatment of the topics involved under this head must be pardoned, in order that all who desire may gain an intelligent view of the mode of origin and general history of this formation—even though they have not access to other sources of information. The topics to be treated here are:

1. The Origin of the Series.
2. Its Paleontology or Vital History.
3. Its Physical History.

The last named topic discusses the formation of the Cincinnati Axis, the relative date of its emergence, the dip of the Blue Limestone beds, and their relations to the formations that surround them.

1. The Cincinnati series, like all of the great limestone strata that enter into the structure of the earth, was formed beneath the sea. Its beds, both of limestone and shale, are wholly of marine origin. This is determined by the remains of plants and animals which the formation contains, the plants being entirely confined to sea-weeds, and the animals belonging to groups that are found only in the sea. By observation of the rock formations that are now growing upon the floor of the ocean, we are able to follow the modes in which all of the stratified deposits of the earth's crust were formed. Sandstones, conglomerates, shales and limestones, agreeing in all of the essential elements of their history with even the most ancient deposits, are now in process of formation under the waters of the sea. We learn that limestones are built up through the agency of the vegetable and animal kingdoms, and that they are mainly derived from the latter. All of the varieties of this class of rocks, with which we become acquainted in the geological scale, can be found to-day in those portions of the sea in which limestone strata are accumulating. The deposits are sometimes made up of the cemented fragments of sea shells, and again we find areas in which limestone mud, derived from the thorough comminution of similar fragments, has hardened into a solid, structureless stone, from which almost every trace of organic origin has been obliterated. At still other points the characteristic coral growths which form the reefs of existing seas, can be seen building up the ocean floor over areas that can only be measured by thousands of square miles. Recent deep-sea explorations have shown that upon the floor of the Atlantic a limestone formation of vast extent, identical in

its general character with the chalk formation of Europe, is now growing, which is almost entirely composed of the microscopic shells of foraminifera, one of the lowest divisions of the animal kingdom.

The beds with which we are dealing are to be referred to these various methods of limestone growth. There are occasionally layers that have a solid and structureless character, but in the great majority of them we can mark the remains of the various living forms of which they are composed. The surfaces of these layers are almost always ornamented with the impressions or casts of bivalve shells, or with branches of corals, and the substance of the rock itself is often found to be made up of precisely similar forms.

The growth of the limestone layers seems to have been interrupted at frequent intervals by the deposition of shale. The clay and sand of the shales, which constitute more than half of their substance, as shown by the analyses already given, must have been derived from the waste of the land that bounded this ancient sea, and must have been transported to its present location by ocean currents. The calcareous portions doubtless have the same origin as the limestones proper. The shales vary greatly in this respect, some of them being highly fossiliferous, constituting in fact the only beds in which many of the rarer and more beautifully preserved fossils of the Cincinnati group are found. Frequently, a block of shale, as it melts away in weathering, leaves the fossils it contains thickly strewn over the whole surface which it occupies. The branching corals are especially well exhibited in this way.

There are, however, many belts of shale, and sometimes those having a thickness of several feet, that are strictly non-fossiliferous. These beds, it will be remembered, are not continuous over large areas. The currents seem to have swept their burdens in one direction for a considerable period, burying and destroying the life that occupied these portions of the sea, while limestone growths were in progress in the clear seas of closely contiguous areas.

The varying proportions of solid stone and shale, in the different sections of the group, indicate the general conditions which influenced the growth of these sections. The Cincinnati beds proper being much more heavily charged with shale than either the Trenton Limestone that underlies, or the Lebanon beds that complete the series, indicate more turbid seas than either—seas, therefore, less adapted to the various life that crowds these other formations. Indeed, that portion of the section known as the middle or Eden Shales might well be named the barren shales, as the 200 feet that compose it are signally unfruitful in paleontological interest.

There are many facts that bear upon the rate of growth of the Blue Limestone beds. Derived, as all their calcareous portions are, from matter that must first have been accumulated and fashioned through the agency of the animal kingdom, it is safe to say that the rate must have been slow, and all careful study of the beds tends to strengthen this conclusion. Attention will be called to a few facts that bear upon it.

It has already been stated that the surfaces of the limestone layers are generally covered with the valves of sea shells. It may be added that while these shells are found in different stages of growth, the great majority of them belong to full-grown individuals, many of them, indeed, indicating in their rugose and thickened valves extreme age. Leaving out of account the living forms that make the substance of the rock itself, we find from the surfaces alone that there was a succession of countless generations upon the floor of the ancient sea, each of which had the amplest time for its growth.

Again there are beds met with in all the upper portions of the series, especially, sometimes 5 or 6 feet in thickness, that are wholly composed of these shells, and that have never been perfectly consolidated into rock. The free valves can be gathered as perfect in form as sea-shells on a modern beach, often retaining the muscular and visceral impressions with the greatest distinctness. Such a shelly band is found in the Cincinnati section at a height of 350 to 360 feet above low water. Others are found in the Lebanon Section. It is of frequent occurrence in this latter division, to find layers composed of these separated valves set upon edge, like dishes packed in a crate. Some of the smaller shells have been so treated, as *Leptaena sericea*, but the most common examples are furnished by the valves of *Strophomena alternata*. To explain such facts, we must suppose that the sea floor was paved with dead shells, which had gathered there from long continued occupation, and that finally, deep currents swept over the floor, arranging the shells as we find them now.

The shales, as will be remembered, have been described as being fossiliferous in some of their beds. Indeed, they are sometimes suprisingly rich in fossils. Many of the most delicate forms of the entire series are found only in these deposits. Certain crinoids and trilobites are rarely seen in other beds. They occur in the shales, in mature and well-grown forms, not at a single horizon, but in frequently repeated beds. These facts seem to imply for the fossiliferous shales a rate of growth almost as slow as that of the limestone itself, for any rapid deposition of the materials of the shale would have destroyed such kinds of life, or, indeed, all

forms, as in fact seems to have been done hundreds of times in the series in those layers of shale which are destitute of fossils.

Another fact that may be mentioned as illustrating this slow rate of growth, is the frequent occurrence of layers composed of nothing but agglomerated masses of small shells. The brachiopod shell—*Zygospira modesta*, Hall—contributes to the Blue Limestone series many successive layers, sometimes several inches in thickness and having a considerable extent. A still more striking example of the same sort is furnished by a small univalve shell, almost microscopic, indeed, which is found throughout the whole Cincinnati Group, but which at about 400 feet above low water at Cincinnati, begins to multiply so as to constitute the very substance of the rock; and from this point upwards for somewhat more than 100 feet, it contributes many layers of the solid limestone. This shell was first brought to notice by that excellent collector, S. T. Carley, whose labors have done so much in disclosing the treasures of this great formation. It has been described by Hall under the name *Microdiscus*, but this generic name having been already appropriated in another division of the animal kingdom, it is desirable that another be substituted.

Perhaps, there is no example that impresses the observer more with the slow rate at which these limestones were formed, than to find inch after inch and foot after foot of solid rock built up by shells so minute that the microscope must be invoked to recognize them.

The parasitic corals that abound to so great a degree in the rocks of this formation furnish still another example. The argument which Lyell makes in regard to the slow growth of the chalk, can be paralleled in almost every particular in the Blue Limestone. Two of the most common forms of these parasitic corals are *Aulopora arachnoidea* and *Alecto inflata*, Hall. They are very often found on the inside of the valves of *Strophomena alternata*, Conrad. Sometimes these valves were first occupied by some forms of *Chætetes*, and after this growth was arrested the delicate webs of the above named corals were traced upon them. To appreciate these facts, we must follow the successive steps of a history which certainly contains the following elements: The brachiopod shell, *Strophomena alternata*, grew upon the bed of a clear sea through all the years required for its complete development. After it died in the station where it grew, time was required for the decay of the muscles and ligaments that held the valves together. After the valves were separated, and while they were still lying on the sea-floor uncovered, a *Chætetes* established itself upon the interior of one of them, and when, after hundreds of its cells had been built there and its course was in some way arrested,

the beautiful network of *Aulopora* or *Alecto* was drawn over all. All of these changes took place without the shell becoming imbedded in sediment, for the moment that the valves were covered, all of the forms of life connected with them would have been destroyed, whether the original molluscan life by which they were built and which they sheltered, or the subsequent coralline forms that took possession of them.

One more example will be adduced, and this is furnished by the growth of those beautiful forms that constitute so marked a feature of the life of the Cincinnati seas, viz: the crinoids. The description of a single locality can stand for a thousand.

In the vicinity of Lebanon is a bed of *Glyptocrinus O'Nealli* (Hall), the specific form and the particular locality of which were discovered by J. K. O'Neall, Esq., of Lebanon. The crinoids are found in a bed of blue clay several feet in thickness, not at one horizon, but scattered through its whole substance. Roots, stems, bodies and expanded arms, the latter often exhibited in a most delicate tracery upon the shales, occur here. The individuals represented are of all sizes. Scarcely an inch of the bed is without its fragments. A study of the facts shows us that we have in these few feet of shale a long succession of generations of crinoids, each individual of which found time to complete its growth without interruption from the slow descending shales. The layers from the River Quarry beds of Cincinnati, that are entirely made up of small crinoidal joints, furnish testimony of the same kind.

In conclusion, it may be said that there are no reasons for believing that the floor of the Cincinnati sea was built up at any more rapid rate by the animal forms that tenanted it, than is the bottom of the tropical oceans of to-day by their living inhabitants. The observations made in this last named field show that in the coral reef region of existing seas, where limestones are most rapidly forming, the rate of gain is about one foot in a century.

2. *The Paleontology or Vital History of the Cincinnati Group.*

Very numerous references have already been made, especially in the treatment of the last preceding topic, to the various living tribes that inhabited the seas in which the Cincinnati Group was formed, the remains of which, indeed, have furnished so large a part of the materials that make up this great series. The fossils of the group are so very abundant, and often so beautifully preserved, that they cannot fail to attract the attention of even the most thoughtless observer. The general interest that they excite is evidenced in the popular identification of these products of deep sea life with various animal and vegetable

forms of the existing creation. The hills of Cincinnati are already counted as classical ground by the geologists of all lands. Sir Charles Lyell said, after visiting these hills and looking over the collections that had been made of their treasures, that there was no other locality known in the world where so large a number and so large a variety of well preserved Lower Silurian forms could be so easily procured.

In treating of the life-history of this series, no description of individual forms will be attempted. This work has already been well begun in the elaborate reports of Hall and Meek and other paleontologists, who have already made such ample contributions to our knowledge of the life of these early ages of the earth. It is believed, however, that some orderly statements as to the modes of occurrence, the association and the range of the leading fossils of these beds, may be made serviceable to the rapidly increasing number of those who desire to understand something of the wonderful history which these rocks contain. Some statements of this sort are necessary, also, to justify the divisions of the series that have been already proposed.

It has been previously stated—at least by implication—that the Cincinnati Group has not a definite boundary in its downward extension. In fact no ground has yet been found, either stratigraphical or paleontological, on which a line of demarcation could be established between the Cincinnati Group and the underlying Trenton limestone. Many of the fossils of the Trenton rise without interruption into the Cincinnati beds, and some of them continue through the whole series. The divisions in the general geological scale of the country, it will be remembered, are founded upon facts that occur on the eastern border of the continent. The limestones of the Trenton period there are overlain by the Utica shales, which in turn are covered by the gray sandstone of Oswego, the two formations being known as the Hudson River Group of the New York geologists. These lithological differences indicate very considerable changes in the seas in which these successive formations were deposited. The mode of accounting for the change proposed by Dana seems probable, and has been very generally accepted. His theory is, that an old sea-wall or mountain-barrier, which shut out from the Trenton seas to the eastward, all the storms and sediments of the Atlantic, was depressed, and in part broken down at the beginning of the Hudson period, and that thus the limestone growths of the border were arrested, and that the areas previously occupied by them thenceforward were the scene of shale and sandstone accumulation. In the interior, however, where the rock now under discussion was forming, no such change is to be noted. There was a relative increase of shale, it is true, but no interruption of life occurred,

and thus the Trenton Group here blends with the Hudson in its lithology and its fossils.

It certainly seems probable that the subsidences in progress upon the borders were synchronous with the elevatory movements that raised the Cincinnati axis; that in fact they stood to these movements in the relation of cause to effect; but there are the best of reasons for believing that these movements of subsidence were in the main exceedingly slow and prolonged through vast periods of duration, and also that the elevatory movements were in like manner gradual and long continued. The depression of the northern barrier alluded to, is but one of a long series of movements taking place upon the border, the results of which are seen in the addition of many thousands of feet of stratified rocks to the Apalachian region.

The fossils of the group belong to both the animal and vegetable kingdoms. The remains of plants are, however, far less abundant and interesting than the animal fossils, which have been already noticed.

The plants of the Blue Limestone belong wholly to the lowest divisions of the vegetable kingdom, and are in all cases of marine origin. It is therefore hardly necessary to say that the popular identification of certain forms found in these rocks, with the twigs and stems and roots of existing land plants, is wholly illusory.

It is quite possible that the term *fucoid*, (sea-weed,) is sometimes made to cover markings upon the rock of inorganic origin, or perhaps, in some cases, the tracks of mollusks, trilobites or annelids, but there is after all quite a large number of forms that belong to this division, and many of them have never been adequately described.

Stems and roots, apparently referable to the genera *Paleophycus* and *Buthotrephis* of Hall, are quite commonly found throughout the whole system. In frequent instances only the impression of the plant is left upon the surface of the stone. A form resembling the *Buthotrephis gracilis* of Hall, is oftener found in this state than in any other. There are but few of them that serve to mark with any accuracy the different horizons of the series. There is one peculiar form, however, that comes in at about 300 feet above low water at Cincinnati, which is constantly found wherever the rocks of this horizon are exhibited. This fossil may be styled the dumb-bell fucoid, as its form would suggest this name to any one who should observe it. They are so often found arranged after the fashion of the cross-bones in the ancient medical symbol, that the collocation hardly seems fortuitous. Although, as has been said, the fossil is met with wherever the proper horizon is exposed, there are still some localities that are much more prolific in it than others. The bed of Obanion Creek, a mile or two above Loveland, furnishes as well-marked

specimens as any point noted. It may be remarked that a similar form reappears in the Waverly Sandstone long afterwards, and is very conspicuously shown in the flaggings of Cincinnati. It has sometimes been held that the form is concretionary in its origin, and indeed the stems sometimes show a concretionary structure, but their occurrence at a definite horizon, through a wide area, without changes in lithological character, to separate its beds from those above and below, seem to set aside this explanation as untenable.

One other peculiar form may be noted. It consists of five or six cylindrical stems radiating from a common center. The stems are from two to three inches long, and agree in form with some that Hall has figured as *Paleophycus*. The only locality in which it has been seen, is near Morris' Hill, Clear Creek township, Warren county. It may be provisionally named *Paleophycus radiata*.

The corals of the Cincinnati Group are quite numerous and interesting. Unfortunately, they have never been made the subjects of as careful and discriminating study by our paleontologists as several other sections of fossils which are found here. It is probable that a considerable number of new varieties or species await recognition, and of the species already established, the descriptions and figures of several are only to be found in foreign works of science.

There are a few of them that mark particular horizons in the series, but most of them have a considerably extended range. A *Lichenalia* (*Lichenalia concentrica?* of Hall,) is found in the River Quarries at Cincinnati, and is characteristic of that portion of the series. The beautiful *Stellipora antheloidea* of Hall, comes in at 300 feet above low water at Cincinati, and holds on well through the Lebanon beds. Coming in at the same elevation, but with a somewhat more contracted range, is the equally beautiful *sword coral* (*Escharapora recta*, Hall.) The various forms referred to *Chaetetes*, have a very wide range, and are by far the most abundant of the corals belonging to the series. The *Porites vetusta*, Hall, now referred to the gems *Protarea*, E. & H., is confined to the Lebanon beds. Near the upper limit of the system it becomes very abundant. As is well known, it is only found upon other shells, corals, &c., but unlike some of the other parasitic corals, it seems to have no preference, occupying alike the valves of various species of *Strophomena*, covering the walls of the *Streptelasma*, or bull's horn coral, that is found at the same horizon, or resorting to various other stations. Two very delicate and beautiful parasitic corals have already been mentioned in another connection, viz., *Aulopora arachnoidea* and *Alecto inflata*, Hall. These are exceedingly common in the Hill Quarries of Cincinnati, and at the same elevation in the series elsewhere, and reaching also to the higher beds.

They occur more frequently than elsewhere in the interior of the valves of *Strophomena alternata.*

Confined exclusively to the upper or Lebanon beds, are several well-marked forms. The most noticeable among them is the cyathophylloid coral, that is commonly held to be the *Streptelasma corniculum* of Hall. It occupies about 100 feet of the series, beginning at a point 150 feet below the summit. During the ages included within these limits, it grew in immense profusion, fairly paving the floor of the sea for wide areas, through hundreds of consecutive beds. The younger forms indicate that it grew in clusters, a half dozen individuals being sometimes rooted at the same point. Specimens illustrating this peculiarity of growth, are very abundant and fine in the railroad cut one-half mile west of Oxford.

The beautiful coral, *Favistella stellata,* Hall, which is the next to be named, acquires considerable interest from the fact that it is one of the characteristic fossils of the Hudson River formation of the east. Its exact position in the scale has not been ascertained so far as the rocks of Ohio are concerned, but at Madison, Ind., it occupies only 2 or 3 feet of the series. This portion, however, it literally fills with its spheroidal and calcified masses, which vary in size, from a few inches to 5 feet in diameter. The bed at Madison lies within 15 feet of the summit of the Blue Limestone series.

Associated with the above named form at Madison, but having a much wider range in Ohio—a species of *Tetradium*—probably *T. fibratum,* Safford, occurs. Its range is not less than 150 feet in Ohio, but at Madison, Ind., it is restricted to an equally narrow and definite horizon with the previously named fossil. It here furnishes in its spherical masses a layer very like the *Favistella stellata* bed, but overlying this bed by an interval of 2 to 5 feet.

There are two species of corals that are found parasitic on the shells of *Orthoceras* and perhaps nowhere else. They have a wide range, but are more abundant in the Cincinnati section than elsewhere.

The *Graptolite* family is not abundantly represented in this formation. One species, however, comes in, at about 50 to 75 feet above low water, which helps to mark the horizon, with a good degree of definiteness. It is found wherever this part of the rock is exposed. It has been described by Hall under the name *Climacograpsus typicalis.* Another species, perhaps *Graptolithus gracilis,* Hall, is found at a higher elevation in the series.

Reference has previously been made to the abundance of crinoidal forms, that these rocks contain. The genera, *Glyptocrinus, Heterocrinus,*

Dendrocrinus, *Hybocrinus*, *Anomalocrinus* and *Homocrinus* are here represented, some of them by several species. The forms found lowest in the series are *Heterocrinus simplex*, Hall, and *H. heterodactylus*, Hall. These constitute, by the joints of their stems at least, a notable portion of the River Quarry beds, and occasionally there are found layers or pockets in the shale, that consist largely of the bodies and stems of *H. simplex*. The bodies in such cases are of small size. Though beginning thus low in the series, these forms hold on through a good part of the Cincinnati division, at least. A variety of *H. simplex*, termed *grandis* by Meek, occurs at 350 feet above low water in the Cincinnati section, associated with the other crinoids that are found there. The somewhat rare form *H. juvenis*, Hall, belongs to the Lebanon beds. The body of this crinoid as compared with the stem is disproportionately small.

The most striking and beautiful, and at the same time the most abundant and best known of the crinoids of the Cincinnati Group, is *Glyptocrinus decadactylus*, Hall. It begins about 300 feet above low water at Cincinnati and its range does not probably exceed 100 feet; it may, indeed, be much narrower. The bodies of this species are generally found as they weather from the shale, though in rare instances they occur with stems attached upon the limestone layers. The finest examples of this sort known, were found at one of the quarries of Eden Park, a year or two since, 17 well-grown crinoids being held on a slab of not more than 3 square feet. *Glyptocrinus decadactylus* is found not only in the Cincinnati hills, but in the corresponding portions of the system everywhere. At Fort Ancient, for instance, and at Lebanon, it is occasionally seen. In considering the great number of species and individuals of fossils that are referred to Cincinnati, it is to be taken into the account that there is no locality in all the district which the Blue Limestone formation occupies, where as fine exposures of the rock are afforded as here.

The occurrence of the *G. O'Nealli* has already been noted under the previous section. Its range in the system is from 600 feet to 700 feet above the Cincinnati base. *G. Baeri*, Meek, also belongs to the Lebanon beds, while *G. Dyeri*, Meek, is closely associated with *G. decadactylus*, Hall, in form and probably in range.

Homocrinus (*Dendrocrinus*) *polydactylus*, Shumard, is also found high up in the series, certainly as high as 650 feet above the Cincinnati base. Its range has not been learned. *Dendrocrinus caduceus*, Hall, also occurs at 700 feet or thereabouts, and has been found in but few localities. Longstreth's branch, near Lebanon, yielded the typical specimens.

Of the Cystideans—a group closely allied to the crinoids—there are

already 8 or 10 described species. Perhaps the most remarkable and interesting forms of this division, are the two described by Hall under the genus *Lichenocrinus*. The anomalies of structure in these forms have greatly perplexed the paleontologists who have studied them, and no decision in regard to them seems yet to have been reached. One at least of the two species thus far described, begins low in the series, being found as abundant as at any other horizon, within 50 feet of the Cincinnati base, and the two together traverse almost all of the remaining beds.

The beautiful forms *Paleaster*, *Agelacrinites* and *Hemicystites* mostly occur in the beds that lie between 300 feet and 500 feet above the base. The horizon of 350 to 400 feet has thus far proved most prolific in them.

The great division of the animal kingdom to which we next come, viz: the Mollusca, is by far the most important of any represented in the Cincinnati rocks. The leading sub-divisions of this branch are all represented here—most of them by many species not only, but by many genera and families as well.

The genera *Tentaculites* and *Conularia* are now generally referred to the Pteropod Mollusks. There are probably true species of *Tentaculites* in the Cincinnati rocks, but several very distinct forms have been heretofore confounded under this genus. All of the forms that are found parasitic on other shells are at once excluded by the reference above made—for the pteropods are free-floating, oceanic genera, whose shells are strewn, when their tenants die, upon the bottoms of the seas at the surfaces of which they spent their lives.

The parasitic forms hitherto confounded with tentaculites are to be referred to tubicolar annelids—a division of the branch *Articulata* or *Annulosa* which includes the *serpulæ* of existing seas—with which the forms in question very closely agree. Two genera of this group are certainly found here, one of which was established upon forms from the Cincinnati horizon, by Prof. H. A. Nicholson, of University College, Toronto. The genera in question are *Ortonia*, Nicholson, and *Conchicholites*, Nicholson. Of *Ortonia*, two species have thus far been described, viz: *O. conica*, Nich., and *O. minor*, Nich. Only one species of *Conchicholites* has been recognized here, and this species was established by Prof. Nicholson, for a unique and beautiful specimen from the cabinet of Dr. H. H. Hill, of Cincinnati. It is termed *C. corrugatus*.

A third genus, viz: *Cornulites*, Schlotheim, probably includes the form that has hitherto been doubtfully identified with *Tentaculites tenuistriatus*, Meek, in the collections of Cincinnati. It is a comparatively rare fossil, and none of the group, unless it be *Ortonia minor*, serve to mark horizons

distinctly. They begin as low down as 300 feet, and continue well through the system.

A beautiful *Conularia* occurs low down in the Cincinnati division, within fifty feet of low water mark. It is probably the *C. Trentonensis* of Hall. One other species is also found at Cincinnati, but both are exceedingly rare shells.

Of the chambered shells, or the shells which constitute the great division *Cephalapoda*, the genera Nautilus, *Orthoceras*, *Endoceras* and *Phragmoceras* are certainly represented.

The genus *Nautilus* is remarkable for the fact that, beginning in the earliest ages of paleozoic time, it has been continued without interruption through all the vast cycles that separate this early day from the present. One species, *N. pompilius*, or the pearly nautilus, is found in the tropical seas of to-day, and is famed alike in fable, poetry and science. One species is found also in the Cincinnati rocks, well up in the series, being not less than 700 feet above the Cincinnati base. It is a comparatively rare shell, but is known at the four following localities: Camden, Preble county; Clarksville, Clinton county; Waynesville, Warren county; and Richmond, Ind. It was described in the Illinois Reports by Meek, under the name *Nautilus Baeri*.

The genus *Orthoceras* is represented by several species, the individuals of some of which are exceedingly numerous, in every part of the series. These shells attract the attention of all observers. They are, quite frequently, popularly identified as petrified rattle-snakes, stone serpents, fishes' back-bones, &c. No facts have been learned in regard to their occurrence and distribution, by means of which they can be turned to account in determining the various horizons of the series.

The statements already made, in regard to *Orthoceras*, apply almost equally well to the sub-genus *Endoceras*.

The genus *Phragmoceras* is known but by a single species, which is found associated with *Nautilus Baeri*, at an elevation of 700 feet above the base. This species seems not to have been described.

Of the Gasteropod shells of the group, there are many species recognized under 12 or more genera. A considerable proportion of these species have a wide range, and quite a number generally occur as internal casts, so that there is difficulty in identifying them.

One comparatively rare form, however, and of very narrow range, *Fusispira* (*Murchisonia*) *sub-fusiformis* of Hall, comes in at an altitude of about 50 feet above low water at Cincinnati.

The horizon of 350 feet is everywhere characterized by a great development and multiplication of various species of gasteropods. Various

species of *Cyclonema* and *Murchisonia* crowd the surfaces of the layers everywhere through the formation at this elevation.

Numerous as are the forms belonging to the groups already passed in review, they constitute but an insignificant fraction of the whole number which this great cemetery contains. If all of the divisions thus far named should disappear from the rocks, although many nooks and corners of the strata would lose their very substance, and the variety of the life represented here would be greatly reduced, the total amount of it would be scarcely affected. That such a statement can be true, results from the overwhelming preponderance that these divisions of the Mollusca next to be named, possess in some of the earlier ages of the world's history, and especially in the rocks now under consideration. The division to which reference is made is the class of *Brachiopods*, or equal-sided mollusks. The brachiopods are bivalve shells, but not of the group to which the cockle-shells and clam-shells and all the bivalves commonly found in the seas of to-day belong. There are but few species of the class now known, but in the seas in which the Cincinnati rocks were formed, the species, genera and families, were exceedingly abundant, and as to the individuals belonging to these higher divisions, they were so enormously multiplied, that they literally filled up the sea with countless numbers of their dead shells through countless ages.

Some of the fossils of this group, from their wide range and great persistence, furnish invaluable assistance to the geologist in identifying the most widely sundered members of the same formation, while others again mark with the greatest precision some particular horizon. Both of these kinds of service are rendered by the brachiopods of the Cincinnati Group. The knowledge that we have of the place of this group in the general geological scale, is largely derived from the shells of this division which it contains, which connect it on the one hand with the Trenton limestone, and on the other with the Hudson group of the eastern border. It is principally on the evidence of the same group of fossils that the minor divisions, already announced, have been established.

A few of the many facts pertaining to the distribution and range of these shells in the Cincinnati Group will now be given. The differences in range exhibited by different species are remarkable, some of the forms coming up from the underlying Trenton, and maintaining themselves through the 800 feet of this series, and even passing into and through the Clinton limestone of Upper Silurian age, while other species are strictly limited to 2 or 3 feet of vertical ascent. A much larger number, however, occupy intermediate ground between these two extremes, ranging through a few tens or scores, or sometimes even through two or three hundreds of feet.

Of the species which are characterized by the longest duration, the number is comparatively small. The following forms may be named as the leading representatives of this division:

Orthis biforata (Eichwald.)
Zygospira modesta (Say.)
Strophomena alternata (Conrad.)
Leptaena sericea (Sowerby.)
Orthis testudinaria (Dalman.)

The two species first named are certainly found in the overlying Clinton limestone, and one of them indeed, *Orthis biforata*, surviving Clinton time, was for ages afterward a tenant of the Niagara seas, and closed its course finally in the later stages of the great formation that was produced in these seas.

But two species can be named, the range of which is known to be very limited, while at the same time the horizontal extension is wide. These two species are:

Strophomena planoconvexa (Hall.)
Orthis retrorsa (Salter.)=*O. Carleyi* (Hall.)

Of others that seem to belong to the same category, may be named:

Strophomena gibbosa (Local name.)
S. sinuata (James.)
S. filitexta (Hall.)
Orthis emacerata (Hall.).

The first named of this group—*Strophomena planoconvexa*—marks an altitude of 300 feet above low water at Cincinnati. Its vertical range is exceedingly restricted, while its horizontal range seems to stretch through the whole area of the Blue Limestone. Besides the many sections in the vicinity of Cincinnati that hold it, its presence has been marked throughout the whole east and west extent of Hamilton and Clermont counties.

Orthis retrorsa is a still more marked example. Its vertical range in scores of measured sections has not been seen to exceed 3 feet, and oftener shrinks to 1 foot, yet it is found with the most unswerving constancy in its own place in the series. This place is very nearly 475 feet above low water at Cincinnati. Wherever the rocks of that elevation are exposed, in every instance so far examined, this fossil has been found. Both of these forms are very abundant in the narrow sections that hold them, the rock being in the latter instance quite largely made up of this shell.

Questions of interest are suggested by the facts here detailed. The conditions for the growth of these animals must certainly have been favorable during the time in which they were thus paving the sea, but their disappearance is as abrupt as their advent. No change in either lithological character or associated fossils occurs with their advent or disappearance. *Orthis retrorsa* inhabited other seas as well. It is assigned to the Anticosti Section by Billings, but *Strophomena planoconvexa*, so far as known, belongs to the Cincinnati Group alone. Both of these forms are abnormal to a certain degree, the latter being one of the two resupinate forms found at Cincinnati, while in the first named form the area of the ventral valve inclines forward, instead of overhanging the hinge line.

The horizon of the *Orthis retrorsa* passes below the level of the Great Miami river at Miamisburg, and of the Little Miami at Cæsar's creek, and is therefore lost beyond these points. From the first named locality to the tops of the hills near Hamilton, and from the second to the highest ground near Morrow, this shell can always be found when its proper horizon is uncovered. It will be noticed that this horizon is only about 20 feet above the highest ground at Cincinnati, or about 30–35 feet above the highest rock bedded there. There seems, however, to be a greater interval between this horizon and the highest stratum of the Cincinnati section to the westward, as at Madison, Indiana.

The following localities may be named in which *S. planoconvexa* has been found, in addition to all the Cincinnati hills that expose its horizon, viz: the river hills below North Bend; do. above New Richmond to Moscow; banks of Polktown run, 3 miles west of Loveland.

Of the shells of greatest vertical range, doubtless *Orthis biforata* is most remarkable. It certainly belongs in the underlying Trenton, but it is seldom met in the lower courses of the Cincinnati Group. It is found abundant for the first time at the horizon of 300 feet—an horizon about which so much paleontological interest is gathered. It does not, when first seen here, exhibit the typical form of the shell altogether, but is comparatively small, and has been referred by the collectors to the variety *O. dentata*, Pander. At an elevation greater by 50 feet, the shell has attained its full size, but does not yet exhibit all of the peculiarities of the typical *O. biforata*. From this point upward through the remainder of the Cincinnati section, this shell is everywhere found, and it is just here that it assumes its most characteristic form. At a height of 425 feet above low water, a belt of rock 2–10 feet in thickness occurs, that is almost entirely composed of the ventricose full-grown shells of *O. biforata*. There are but few localities in the Cincinnati section high

enough to expose this bed, but it is found to be one of the most constant of the paleontological horizons of the whole group. It can be followed through all of the exposures of the Blue Limestone to the north and east, until it dips below the higher beds. It is found at the level of the Great Miami river near Franklin, and of the Little Miami near Fort Ancient. Beyond these points, of course, it is lost to view, but between them and Cincinnati it is found wherever the ground is high enough to hold it. It is virtually the summit of the Cincinnati section and the base of the Lebanon beds, so that it furnishes the means of determining the thickness of this great series. In addition to this, the two very interesting questions of the dip of the strata, and the location of the axis of the Cincinnati fold, can be best approached by following the varying elevations of this wide-spread sheet of molluscan life.

The 10 feet of *Orthis biforata* carry us back to a time in the history of the Cincinnati seas, when the conditions were wonderfully favorable for its development. To build up this bed, countless generations must have lived and died here. The shells are, in almost every instance, full-grown forms; they are often ribbed and ridged with age. Perhaps no single line of facts shows us more clearly how slowly these beds were formed.

The sharp-winged variety, *O. prolongata*, Owen, belongs exclusively to the Lebanon beds. It occupies the last 200 feet of the system.

A second shell of the widest range is *Strophomena alternata*. It, too, comes up from the underlying Trenton and extends throughout the whole group. There are certainly as many varieties of this shell as of the one previously named. Most of these modifications come in at the interesting horizon to which reference has so often been made, viz 300–350 feet above low water. *S. nasuta* (Conrad), *S. alternistriata* (Hall), *S. camerata* (Conrad), *S. tenuilineata* (Conrad), and several other more or less distinct varieties belong at or near this horizon, associated with the typical form which does not disappear when the new varieties come in, as is the case with the previously named fossil. The varieties, it may be added, are mostly short-lived.

Leptaena sericea, like the two shells already named under this head, enjoys a very great vertical range. Its horizontal range is also very wide. Both *Orthis biforata* and *L. sericea* are European as well as North American fossils. The latter is found in large numbers in all portions of the system, but from 600 to 700 feet above low water it attains a greater size than elsewhere, and is also found in unusual abundance.

Orthis testudinaria is another form common to both continents, and to

at least two geological formations, viz: the Trenton and Cincinnati formations. There are several well marked varieties of it. In the Eden shales a form is found called *O. elegans?* by Conrad, and *O. multisecta*, by James. At a somewhat greater elevation, but probably below 300 feet, the form called *O. emacerata*, by Hall, occurs. A larger form above the Cincinnati horizon, coming into the series, indeed, at 530 feet above the Cincinnati base, is the one that generally receives the specific designation *testudinaria*. It would seem, however, that the last named variety has not as good a claim upon this title as the lowest form, which is certainly nearer to the horizon from which the species was first described.

The vertical ascent of *O. emacerata* is very small. Whether its horizontal distribution is as wide as sundry of the other forms of the same limited vertical range, already noticed, it is impossible to say. It has been found in but few localities outside of the Cincinnati district, viz: near Morrow, and near Brookville, Ind. It is to be observed, however, that it belongs to a portion of the series comparatively bare in economical and paleontological interest, and that it may have thus escaped more frequent notice.

Both the upper and lower forms occur in boundless profusion at their own place in the system. They are probably the most numerous in individuals of any shells in the Cincinnati Group.

The instances already given serve to illustrate the general modes of occurrence and distribution of the fossils found in these strata, whether of narrow or wider range, but a few facts will be added in regard to some forms of special interest. In Hall's *Paleontology of New York, Vol. I.*, three species of Orthis are described under the names, *O. occidentalis*, *O. sinuata*, *O. subjugata*, which, in later reports, Prof. Hall reduced to one, viz: *O. occidentalis*. There seems to be no certainty among the Cincinnati collectors as to the form *O. subjugata*, but that at least two specific names are needed for these forms, seems evident from the different distribution which they have. *O. sinuata*, as heretofore recognized, comes in at 350 feet above the base, and is very abundant and well developed through the rest of the Cincinnati section, while *O. occidentalis*, as it has been identified, a somewhat smaller shell and characterized by a mesial sinus in the dorsal valve, does not occur at all, or but very rarely in this section, but is only found in the Lebanon beds. It is in these higher beds associated with *O. sinuata*, but is never as abundantly found.

The shells that are introduced in the Lebanon section constitute a very interesting division of the paleontology of this group. Some of them have been already noted, but their names may be repeated here in asso-

ciation with the other leading forms that characterize this division. The list of brachiopods found here, and not in the Cincinnati section, takes in

Orthis retrorsa (Salter.)
O. testudinaria, larger form (Dalman.)
O. biforata—var. prolongata (Owen.)
O. occidentalis (Hall.)
O. subquadrata (Hall.)
O. insculpta (Hall.)
Strophomena tenuistriata (Sowerby.)
S. planumbona (Hall.)
S. sulcata (Verneuil.)
S. filitexta (Hall.)
Rhynchonella capax (Conrad.)
R. dentata (Hall.)

The first of these to come in is *Strophomena tenuistriata*. Its lowest horizon is at the very summit of the Cincinnati hills, or about 455 feet above low-water, and from this point it ranges nearly through the series. A form that has received the local name, *S. gibbosa*, which resembles very closely *S. tenuistriata*, is found 350 feet below this point, in a section shown in Crawfish run, above Pendleton. It occupies but a single layer of the rock where it is to be seen, and no form resembling it has yet been found, until at the elevation above named.

Orthis retrorsa is the next new form met with. Its altitude above the Cincinnati base is 475 feet. Its range and distribution have been already discussed.

O. testudinaria is met with at an elevation of 540 feet above the base.

Strophomena planumbona and *Rhynchonella capax* are first seen at 600 feet above base; *Strophomena filitexta*, a rare shell, was marked in a single instance only at 620 feet.

Orthis subquadrata begins at about 650 feet, and has a range of 100 feet.

O. insculpta has a narrower range, and is not an abundant shell. It seems to occur in colonies at various elevations. This latter statement can also be made in regard to *Strophomena sulcata*. Both of these shells are found in pockets, great numbers occurring in a very limited space. They nowhere exhibit the wide sheets of distribution which characterize some of the forms already described. The range of both is between 650 and 750 feet above the Cincinnati base.

Of the *Lamellibranch Mollusks*, or ordinary bivalve shells, there are many species found in this group. They will not, however, be considered here, as they are not found to add much to the testimony already furnished by the groups that have been made to pass in review, as to the

subjects under discussion. The fossils of this division are very generally found as internal casts, and are, therefore, identified with more difficulty than the most of those that have been already noticed.

One other division of the Animal Kingdom, was quite largely represented in the Cincinnati seas, viz: the branch *Articulata.* It contributed two at least of the groups of animals found as fossils in these beds—the remarkable division called *Trilobites*—an exclusively paleozoic form of life, and the less conspicuous division of bivalve crustaceans, most of which fall under the genus *Leperditia.* With a brief account of the distribution of the trilobites, this section of the report will be concluded.

There are probably not less than 20 species of trilobites now represented in the various collections of Cincinnati fossils. Some of them are known by only one or two fragments, while others again are as perfectly preserved and as striking fossils as any that are found in the series. Some of the species have a scarcely less extended range than that enjoyed by the brachiopod shells already described, beginning like them in the Trenton limestone, and holding on through all the Cincinnati division. The best examples of this sort are *Calymene senaria,* Conrad, and some of the species of *Asaphus.* The first of these forms is by far the most abundant trilobite in the series. The collection of Israel H. Harris, Esq., of Waynesville, contains nearly a thousand specimens of this fossil. The whole rock is frequently made up for several inches in thickness, of its rings and shields, the outer covering of the animal being probably periodically cast or moulted.

Some of the species of *Asaphus* attain the largest size of any animals preserved in the Blue Limestone beds. Dr. Locke published the figure of one which he restored from fragments, the length of which he estimated to be 2 feet. A length of 18 inches can frequently be inferred from the fragments that are met with.

Trinucleus concentricus, Eaton, marks the lowermost 100 feet of the Cincinnati section. Through this portion of the series, it is quite abundant. It occurs also very sparingly in somewhat higher beds, but probably never at a greater elevation than 150 feet above low-water.

The narrowest range that can be definitely marked, is that shown by *Triarthrus Becki,* Green. It belongs about 25 feet above low water. The best point to reach it at present, is Taylor's creek, back of Newport, Ky. Some interest is connected with the occurrence of this fossil here, because it is counted quite a characteristic fossil of the Utica shale, of Eastern New York. It belongs, however, in the Trenton of the same region, so that no parallelism of formations is effected by this trilobite, which other fossils are unable to establish. The most that can be said

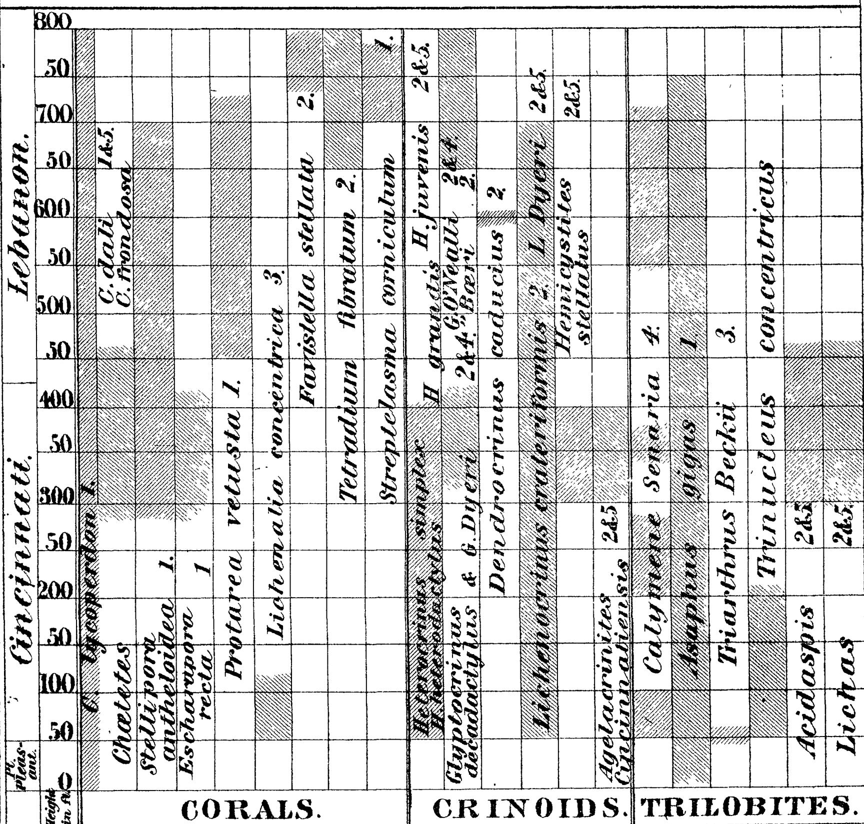
TABLE 1.

showing the range of some of the principal

CORALS, CRINOIDS, CYSTIDEANS & TRILOBITES

OF THE

CINCINNATI GROUP.



Explanation.

1. *Distribution general or universal.*
2. *Distribution limited to a few localities.*
3. *Fossils strictly limited to one horizon of little vertical range.*
4. *Occurring in Colonies.*
5. *Limits unknown.*

Spaces occupied by Fossils are shaded.

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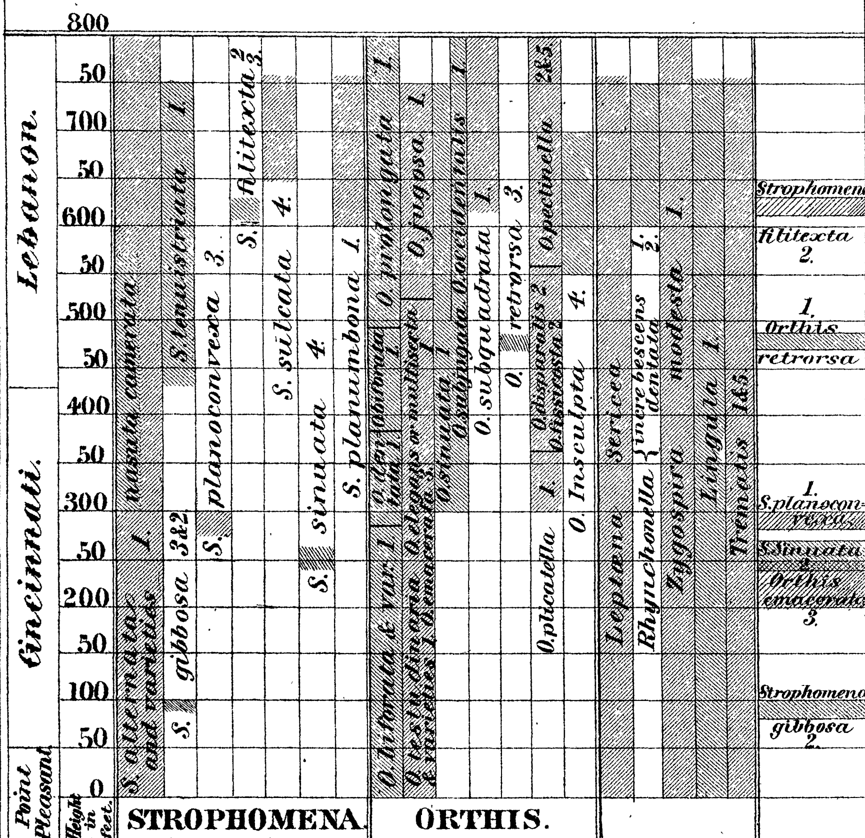
TABLE 2.

showing the range of the

PRINCIPAL BRACHIOPODS

OF THE

CINCINNATI GROUP.



Explanation. *Spaces occupied by fossils are shaded.*

1. *Distribution general or universal.*
2. *Distribution restricted to a few localities.*
3. *Limited strictly to one horizon of little vertical range.*
4. *Occurring in Colonies.*
5. *Limits unknown.*

All of the forms named in the right-hand column are strictly limited to the horizon at which they are shown.

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in regard to it, is, that it suggests the low water beds of Cincinnati as the equivalent of the Utica shale.

A greater number of species belong to the genus *Acidaspis* than to any other, but perfect forms of any are very rare, and some of them are thus far known by fragments only.

The genus *Ceraurus* is also represented by two or three very rare and beautiful species. All of these last named forms are found above the horizon of 300 feet.

The leading facts to which attention has been drawn, in the foregoing discussion, are embodied in the following tables, which indicate the range of many of the most abundant and characteristic fossils of the formation. Pains have been taken to make the tables embody the facts so far as known, but they are to be regarded as only approximately true. It will be easy, however, to correct and extend them by subsequent discoveries, or by knowledge now in the possession of others.

A catalogue of the fossils of the group is also appended. It is based upon a catalogue published in August, 1871, by U. P. James, Esq., of Cincinnati. This list is intended to include all the fossils of the group of which adequate descriptions have been published.

Mr. James's catalogue includes quite a large number of proposed species, which are here omitted, because they have not yet been fully authenticated. The list is further reduced by the omission of doubtfully identified forms, and in general, only those fossils are named here, about the occurrence of which, in the Cincinnati rocks, no question can be raised. The labor of arranging this list, and of looking up the authorities cited, has been almost entirely done by Mr. James, to whom great credit is due, not only for this service, but also for a great amount of discriminating and careful work upon the fossils of this division.

CATALOGUE OF THE DESCRIBED FOSSILS OF THE CINCINNATI GROUP AS SHOWN IN SOUTH-WESTERN OHIO.

PLANTAE.

Buthotrephis gracilis ....Hall.
Palaeophycus tubularis..H.
Rusophycus bilobatus...H.
R.............. pudicus...H.

SPONGIAE.

Genus ASTYLO-SPONGIA. (Roemer.)

Astylo-spongia ....sp. undetermined.

RADIATA.

ZOOPHYTA.

Genus ESCHARAPORA. (Hall.)

Escharapora recta..Hall.

Genus STELLIPORA. (Hall.)

Stellipora antheloidea..Hall.

Genus STREPTELASMA. (Hall.)

Streptelasma corniculum (?)...Hall.

Genus CHAETETES. (Fischer.)

Chaetetes lycoperdon...Say.
C.............. mammulata (?)..D'Orbigny.
C.............. petropolitanus (?) ....Pander.
C.............. frondosa ....D'Orbigny.

Genus MONTICULIPORA. (D'Orbigny.)

Monticulipora Dalei...E. and H.
M................. papillata...E. and H.

GENUS PTILODICTYA. (LONSDALE.)

PTILODICTYA shafferi..Meek.

GENUS COLUMNARIA.

COLUMNARIA alveolata..Goldfuss.

GENUS PROTAREA. (EDWARDS & HAIME.)

PROTAREA vetusta..Hall.

GENUS TETRADIUM.

TETRADIUM fibratum..Safford.

GENUS INTRICARIA. (DEFRANCE.)

INTRICARIA (?) reticulata..Hall.

GENUS HELOPORA. (HALL.)

HELOPORA fragilis..Hall.

GENUS FAVISTELLA. (HALL.)

FAVISTELLA stellata..Hall.

GENUS PHAENOPORA. (HALL.)

PHAENOPORA ensiformis (?)..Hall.

GENUS RETEPORA.

RETEPORA (?) angulata..Hall.

GENUS AULOPORA.

AULOPORA arachnoidea..Hall.

GENUS ALECTO.

ALECTO (?) inflata..Hall.

GENUS STICTOPORA. (HALL.)

STICTOPORA fenestrata..Hall.
S.............. raripora..H.
S.............. acuta..H.

GENUS LICHENALIA. (HALL.)

LICHENALIA concentrica (?)..Hall.

Genus GRAPTOLITHUS. (Linnaeus.)

Graptolithus bicornis .... Hall.
G................ gracilis .... H.
G................ (undetermined sp.)..

Climacograpsus typicalis.. Hall.

ECHINODERMATA—CRINOIDEA.

Genus GLYPTOCRINUS.

Glyptocrinus decadactylus.. Hall.
G................ O'Nealli .... H.
G................ Dyeri.. Meek.
G................ Dyeri, var. subglobosus.. M.
G................ Baeri .... M.
G................ parvus.. Hall.

Genus HETEROCRINUL.

Heterocrinus simplex.. Hall.
H................ heterodactylus.. H.
H................ subcrassus .... Meek & Worthen.
H................ juvenis .... Hall.
H................ exilis .... H.
H................ constrictus .... H.
H................ exiguus.. H.
H................ laxus .... H.
H................ isodactylus.. H.

Genus POTERIOCRINUS. (Miller.)

Poteriocrinus posticus.. Hall.

Genus LICHENOCRINUS. (Hall.)

Lichenocrinus Dyeri .... Hall.
L................ crateriformis .... Hall.

Genus ANOMALOCRINUS.

Anomalocrinus incurvus .... Meek & Worthen.

Genus DENDROCRINUS. (Hall.)

Dendrocrinus Casei .... Meek.
D................ caduceus.. Hall.
D................ Cincinnatiensis .... Meek.
D................ Dyeri .... Meek.
D................ polydactylus.. Shumard.

ECHINODERMATA—CYSTIDEAE.

GENUS PALASTERINA. (McCOY.)

PALASTERINA (?) Jamesi .... Dana.

GENUS PALAEASTER. (HALL.)

PALAEASTER Shaefferi .... Hall.
P............... incomptus.. Meek.
P............... Dyeri.. M.
P............... speciosus.. M.

GENUS PROTASTER. (FORBES.)

PROTASTER (?) granuliferus.. Meek.

GENUS STENASTER.

STENASTER grandis.. Meek.

GENUS AGELACRINUS. (VANUXEM.)

AGELACRINUS Cincinnatiensis .... Rohmer.
A............... vorticellata.. Hall.
A .... pileus .... H.

GENUS HEMICYSTITES. (HALL.)

HEMICYSTITES stellatus.. Hall.
H............... granulatus.. H.
H............... altus .... Meek.

GENUS CYCLOCRINITES.

CYCLOCRINITES (?) ....

GENUS LEPOCRINITES. (CONRAD.)

LEPOCRINITES Moorei .... Meek.

GENUS ANOMALOCYSTITES (*Ateleocystites.*) (HALL.)

ANOMALOCYSTITES balanoides.. Meek.

MOLLUSCA.

PTEROPODA.

GENUS TENTACULITES. (SCHL.)

TENTACULITES Sterlingensis.. Meek & Worthen.

GENUS CONULARIA. (MILLER.)

CONULARIA papillata (?).. Hall.
C............... Trentonensis.. H.

CEPHALOPODA.

Genus NAUTILUS. (Breynius.)

Nautilus Baeri..... ....Meek & Worthen.

Genus ORTHOCERAS. (Breynius.)

Orthoceras multicameratum..Conrad.
O.............. junceum..Hall.
O.............. amplicameratum..H.
O.............. coralliferum (?)..H.
O.............. Ortoni..Meek.

Genus ONCOCERAS. (Hall.)

Oncoceras constrictum..Hall.

Genus ENDOCERAS. (Hall.)

Endoceras subcentrale..Hall.
E............. longissimum..H.
E............. proteiforme..H.
E............. annulatum..H.
E............. proteiforme, var. strangulatum..H.

Genus GOMPHOCERAS. (Sowerby)

Gomphoceras (undermined sp.)..

Genus PHRAGMOCERAS. (Broderip.)

Phragmoceras (undermined sp.)..

Genus TROCHOLITES.

Trocholites ammonius ....Conrad.

GASTEROPODA.

Genus CYCLONEMA. (Hall.)

Cyclonema bilix..Conrad.
C.............. phaedra..Billings.
C.............. percarinata..Hall.
C.............. Montrealensis (?)..Billings.
C.............. varicosa ....Hall.

Genus PLEUROTOMARIA. (De France.)

Pleurotomaria subconica......Hall.
P...... subtilstriata......H.
P...... umbilicata......H.
P...... ambigua......H.
P...... lenticularis......Sowerby.
P...... (scalites) tropidophora......Meek.
P...... parvulus......Hall.

Genus MURCHISONIA. (Phillips.)

Murchisonia gracilis......Hall.
M...... bellacincta......H.
M...... perangulata......H.
M...... angustata......H.
M...... bicincta......H.
M...... tricarinata......H.

Genus HOLOPEA. (Hall.)

Holopea paludiniformis (?)......Hall.
H...... obliqua......H.

Genus BELLEROPHON. (Montfort.)

Bellerophon bilobatus......Sowerby.

Genus CYRTOLITES. (Conrad.)

Cyrtolites ornatus......Conrad.
C...... compressus......C.
C...... Dyeri......Hall.
C...... costatus......James.
C...... inornatus......Hall.

Genus FUSISPIRA. (Hall.)

Fusispira terebriformis......Hall.
F...... subfusiformis......H.

Genus BUCANIA. (Hall.)

Bucania expansa......Hall.

Genus RAPHISTOMA. (Hall.)

Raphistoma planistria......Hall.

Genus CARINAROPSIS. (Hall.)

Carinaropsis patelliformis......Hall.

BRACHIOPODA.

Genus STROPHOMENA. (Blainville.)

Strophomena alternata........Conrad.
S........ alternistriata........Hall.
S........ camerata........Conrad.
S........ filitexta........Hall.
S........ gibbosa........James.
S........ nasuta........Conrad.
S........ nutans........James.
S........ planumbona........Hall.
S........ planoconvexa........H.
S........ philomena........Billings.
S........ subtenta........Conrad.
S........ sulcata........Verneuil.
S........ sinuata........James.
S........ tenuistriata........Sowerby.
S........ tenuilineata........Conrad.

Genus LEPTAENA. (Dalman.)

Leptaena sericea........Sowerby.

Genus ORTHIS. (Dalman.)

Orthis biforata, var. lynx........Eichwald.
O........ borealis........Billings.
O........ centrilineata........Hall.
O........ costata........H.
O........ clytie........H.
O........ dichotoma........H.
O........ erratica........H.
O........ dentata........Pander.
O........ disparilis........Conrad.
O........ emacerata........Hall.
O........ ella........H.
O........ eccentrica........James.
O........ fissicosta........H.
O........ insculpta........H.
O........ Jamesi........H.
O........ laticostata........James.
O........ occidentalis........Hall.
O........ orthambonites (?)........Pander.
O........ pectinella........Conrad.
O........ prolongata........Owen.
O........ profunda sulcata........O.

O........ perveta..Conrad.
O........ plicatella ....Hall.
O........ triplicatella..Meek.
O........ retrorsa ....Salter.
O........ subquadrata...Hall.
O........ sinuata...H.
O........ subjugata...H.
O........ testudinaria...Dalman.

Genus RYNCHONELLA. (Fischer.)

Rynchonella capax...Conrad.
R.................. dentata ....Hall.

Genus LINGULA. (Bruguiere.)

Lingula quadrata...Eichwald.
L.......... attenuata...Sowerby.
L.......... riciniformis..Hall.

Genus LEPTOBULUS. (Hall.)

Leptobulus lepis..Hall.

Genus PHOLIDOPS. (Hall.)

Pholidops Cincinnatiensis..Hall.

Genus TREMATIS. (Sharpe.)

Trematis millepunctata..Hall.
T............. terminalis ....Conrad.

Genus CRANIA. (Retzius.)

Crania filosa ....Hall.
C......... subtruncata...H.
C......... laelia...H.
C......... leoni ....H.
C......... scabiosa ....H.

Genus OBOLELLA. (Billings.)

Obolella cingulata ....Billings.

Genus ZYGOSPIRA. (Hall.)

Zygospira modesta...Say.
Z............. Headi...Billings.
Z............. Cincinnatiensis ....James.

Genus RETZIA. (King.)

Retzia granulifera..Meek.

LAMELLIBRANCHIATA.

Genus CYPRYCARDITES. (Conrad.)

Cypricardites subtruncata..........Hall.
C.......... ventricosa..........H.

Genus DOLABRA. (McCoy.)

Dolabra (?) carinata..........Meek.

Genus TELLINOMYA. (Hall.)

Tellinomya Cincinnatiensis..........Hall.
T.......... obliqua..........H.
T.......... gibbosa..........H.
T.......... levata, var. occidentalis..........Meek.
T.......... cuneata (?)..........Hall.
T.......... pectenculoides..........H.

Genus NUCULA. (Lamarck.)

Nucula poststriata..........Conrad.

Genus CLEIDOPHORUS. (Hall.)

Cleidophorus planulatus..........Conrad.

Genus LYRODESMA. (Conrad.)

Lyrodesma plana..........Conrad.
L.......... Cincinnatiensis..........Hall.

Genus PYRENOMOEUS. (Hall.)

Pyrenomoeus cuneatus..........Hall.

Genus CYRTODONTA. (Billings.)

Cyrtodonta Hindi..........Billings.

Genus MEGAMBONIA. (Hall.)

Megambonia Jamesi..........Meek.

Genus SEDGWICKIA. (McCoy.)

Sedgwickia (?) fragilis..........Meek.
S.......... (?) compressa..........M.
S.......... (Grammysia ?) neglecta..........M.

Genus MODIOLOPSIS. (Hall.)

Modiolopsis anodontoides..........Conrad.
M.......... modiolaris..........C.
M.......... curta..........Hall.

M............... truncata ....H.
M............... pholadiformis........ ....Foster & Whitney.
M............... faba ....Conrad.

Genus AMBONYCHIA. (Hall.)

Ambonychia radiata...Hall.
A................. obtusa ....H.
A................. costata ....James.
A................. bellastriata ....Hall.
A................. alata ....Meek.

Genus AVICULA. (Klein.)

Avicula insueta...Conrad.
A........... demissa ....C.

Genus ORTHONOTA.

Orthonota contracta...Hall.
O............... pholadis ....Conrad.
O............... parallela ....Hall.

Genus ANODONTOPSIS. (McCoy.)

Anodontopsis (?) Milleri...Meek.
A.................... unionoides..M.

Genus CARDIOMORPHA. (DeKonninck.)

Cardiomorpha obliquata ....Meek.

ARTICULATA.

CRUSTACEA — TRILOBITES.

Genus CALYMENE. (Brongniart.)

Calymene senaria..Conrad.
C............. Christyi..Hall.

Genus ACIDASPIS. (Murchison.)

Acidaspis crosotus ....Locke.
A............ rhynchocephalus (?)...Meek.
A............ ciralipta ....Anthony.

Genus LICHAS. (Dalman.)

Lichas Trentonensis..Conrad.

Genus CERAURUS. (Green.)

Ceraurus pleurexanthemus ....Green.
C............ icarius ....Billings.
C............ perforator ....B.

Genus TRINUCLEUS. (Lhwyd.)

Trinucleus concentricus..Eaton.

Genus TRIARTHRUS.

Triarthrus Becki ....Green.

Genus ASAPHUS. (Brongniart.)

Asaphus gigas ....DeKay.
A......... megistos..Locke.
A......... maximus (?) ....L.

Genus DALMANITES. (Emmerich, Barrande.)

Dalmanites Carleyi ....Meek.
D.............. brevieops..H.

Genus PROETUS. (Steininger.)

Proetus parviusculus ....Hall.
P .... Spurlocki ....Meek.

Genus LEPERDITIA.

Leperditia cylindrica ....Hall.
L.............. minutissima..H.

Genus BEYRICHIA.

Beyrichia tumifrons..Hall.
B............. oculifer..H.

Genus CYTHERE. (Muller.)

Cythere Cincinnatiensis..Meek.

ANNELIDA—TUBE WORMS.

Genus ORTONIA. (Nicholson.)

Ortonia conica ....Nich.
O......... minor ....Nich.

GENUS CONCHICHOLITES. (NICHOLSON.)

CONCHICHOLITES corrugatus ....Nich.

GENUS CORNULITES. (SCHLOTHEIM.)

CORNULITES (?) (undetermined sp.)..

3.—*Physical History of the Cincinnati Group.*

It remains to consider, as the third topic of this general division, the *Physical History of the Cincinnati Group.* The subjects to be treated under this head are the following:

A. *The Cincinnati Anticlinal*—including a discussion of the dip of its beds.

B. *The Date of its Upheaval*—as determined by its relations to surrounding formations.

A. The gentle fold in the strata of the Mississippi Valley, which traverses the central regions of Tennessee and Kentucky, and which afterwards enters Ohio in its south-western corner, passing thence across the State to Canada in a direction a little east of north, has long been recognized under the name of the *Cincinnati Anticlinal*, or the *Cincinnati Axis.* Its location and direction seem to point it out as one of the earliest, though certainly one of the least conspicuous of the great system of folds or wrinkles which constitute the Apalachian Mountain System. The relations of this axis to all the regions that it traverses, are very important, but attention will here be invited only to its connections with the geology of south-western Ohio.

The designation by which this ancient uplift is known, viz., the Cincinnati anticlinal axis, carries with it the important fact that we find here a line or tract from which the strata dip on both sides in opposite directions. The strata, for example, that are found in the tops of the Cincinnati hills, can be followed to the eastern side of Brown county, where they are seen to disappear beneath the river, with a marked easterly dip, while below Cincinnati, near Madison, Ind., the same beds are carried beneath the river by a strong westerly dip. The fact that, starting from Cincinnati, and moving either east or west, one ascends, in the geological scale, by the same steps, is familiar to all who are acquainted with the scope of country involved. The coal deposits of Ohio and Indiana are reached by journeys of nearly the same distance from Cincinnati over outcrops of the same intervening formations. The real existence of this axis, then, is evident from these facts of common observation.

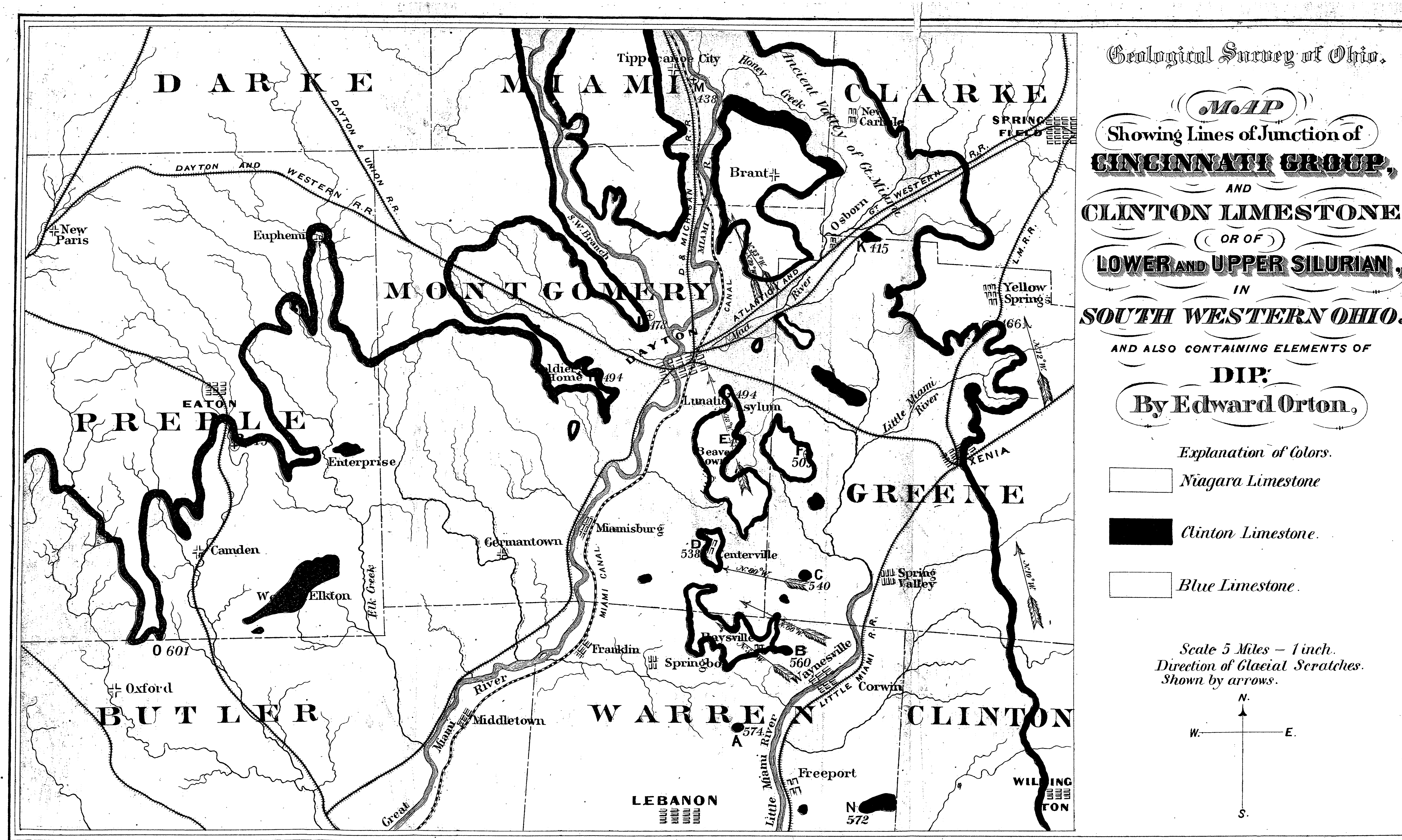
A more difficult question is raised when the location of the axis is considered. In the Geological Report of thirty years ago, Dr. Locke stated that by correspondence with Dr. D. D. Owen, who was at the time examining the geological structure of Indiana, the conclusion had been reached that this axis lay very close to the western boundary of the State. He gave, however, none of the facts on which this conclusion was founded. Dr. Locke's work was in the main very accurate, but there are good reasons for rejecting the judgment which he formed in regard to this question. The central line of the fold lies certainly to the eastward of the State line.

It is important just here to mark the following fact distinctly, viz., that there is quite a broad tract at the summit of the fold in which the beds have but little dip. It is hard to speak of an axis without involving the idea of a line, but there is, probably, no part of this region of less than a score of miles in breadth that deserves, by way of excellence, the name of the Cincinnati axis. In other words, this fold in Ohio has a broad and flat axis, rather than a linear one.

In determining the dip of these Blue Limestone beds in their lower portions, the horizon which it has been found easiest to follow, and upon which consequently most reliance has been placed, is the one already named as furnishing the crown of the Cincinnati section and the base of the Lebanon beds, viz., the heavy stratum of *Orthis biforata*, which is found in Cincinnati at a height of 425 feet above low water. A higher elevation of this bed is certainly found to the eastward.

The plan of the present Geological Survey and the scale on which its work was ordered, has rendered impossible any nice determination of questions of this sort. Comparatively little instrumental leveling has been done, and recourse has been mainly had to the aneroid barometer and to railroad surveys, the levels of which were accessible. The aneroid cannot be depended upon for close and reliable work, and it is not often that the railroad surveys traverse the localities in which precise figures can be made most serviceable. By the combination, however, of such facts as can be gained from these sources of information, it has been found that the horizon in question reaches, near Bethel, on the eastern side of Clermont county, an elevation of 475 to 490 feet, against 425 feet in Cincinnati. From that point it falls quite rapidly toward the east. A similar line of facts has been reached in all observations on this stratum, in which east and west dips were taken into the account.

It seems thus to be rendered certain that the highest portion of the fold is to be sought east of Cincinnati, rather than at that locality, or to the westward. This conclusion, however, involves another for which



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we are scarcely prepared, viz: that the Cincinnati anticlinal, unlike the folds of the Apalachian system generally, has its longer slope to the westward, and its steeper descent towards the east.

Another series of facts has, however, been obtained, bearing upon the dip of another portion of the Blue Limestone beds, in regard to which more precise and definite statements are possible. That the results in the latter case do not entirely harmonize with those already given, may be due to the fact that almost a degree of latitude separates the two lines of observation, and there is thus room for a change to occur in the elements of the dip. The last results seem to show us the northern boundary of the Cincinnati uplift.

The line of junction between the Blue Limestone and the Cliff Limestone, or, in other words, between the Lower Silurian and Upper Silurian formations, is a very well marked horizon in south-western Ohio. An abrupt change in the character of the beds in passing from the one formation to the other, renders it possible to determine with minute accuracy the elevation of widely separated localities in the same geological horizon. Dr. Locke availed himself of this series of facts, in the determination of the dip which he made thirty years ago. He took, however, the altitude of but four of these points of junction, and of this number, one, viz: that of the summit of the Blue Limestone series near Dayton, was determined barometrically, and his figures are proved by instrumental measurement to be 18 feet below the true elevation, while in the case of the altitude below Troy, he failed, from want of suitable exposures, to find the proper boundary. A heavy cut of the Dayton and Michigan Railroad which has since been made at this point, renders it as satisfactory as possible for this purpose, and instrumental measurements show the elevation assigned by Dr. Locke to be 74 feet below the true level. Of course, these errors entirely destroy the value of this previous determination.

For the present calculation, a number of stations have been selected, the elevations of which have been determined with precision. The accompanying map, which shows the sinuous outline of this geological boundary, together with the principal outliers of the Cliff Limestone, will give a clear idea of the facts involved. The stations selected are marked by the letters of the alphabet, and their elevations above low water at Cincinnati are denoted by figures placed near. The two elevations used by Dr. Locke in Butler and Preble counties, are also added, on his authority. It is, however, impossible to determine with exactness, the horizon which Dr. Locke assumed as the summit of the Cincinnati system, and the results obtained by the use of these stations are not,

therefore, entitled to the same degree of confidence which other measurements deserve. It may also be added that station *O* has an altitude exceptionally great, being twenty-six feet higher thon any other point of junction measured in this district.

The following are the stations at which the altitude of the Blue Limetime series has been determined. In taking these levels, the aim has been to reach precisely the same horizon in every instance, and for this purpose, the red band of the Medina Shales which furnishes a conspicuous mark, has been adopted as the summit of the series wherever it is shown. Where it is not found, there is the possibility of a slight deviation from the true horizon, but the error in such cases is confined within the limits of a very few feet.

Altitudes of upper limit of the Cincinnati Group, (Junction of Cincinnati Group and Clinton Limestone,) above low-water of the Ohio River, at Cincinnati.

Stations.		Feet.
A.	Morris's Hill, north-east of Lebanon	574
B.	S. Burnett's farm, west of Waynesville	560
C.	M. Berryhill's farm, west of Spring Valley	541
D.	Centerville, Montgomery county	538
E.	Beavertown, Montgomery county	499
F.	Shoup's Quarry, south-west of Harbine's	503
G.	Dickey's Quarry, east of Dayton	494
H.	Soldiers' Home, west of Dayton	494
I.	Odlin's Quarry, north-west of Dayton	478
K.	Osborne, one mile above depot	415
L.	Goe's Station, above Xenia	466
M.	High Banks, between Troy and Tippecanoe	438
N.	Spring Hill, on Lebanon and Wilmington road	572
O.	Ratcliff's, Butler county, (by Locke)	601
P.	Halderman's, below Eaton, (by Locke)	515

Station *K* gives results that are somewhat out of harmony with those obtained from the other altitudes. By reference to the map, it will be seen that this station is located on a small outlier of Clinton Limestone. It is possible that the whole margin of the outlier is depressed a little below its normal level.

By the aid of the table of altitudes just given, and of the scale of miles laid down upon the map, it is possible to make an extended series of comparisons, a few of which are here introduced.

1. Between Station *A* and Station *M*, which are separated from each other by an interval of 35 miles, on a line almost due *north and south*, the Blue Limestone descends 136 feet, or an average of 4 feet in one mile.

2. Between Stations A and L, distant from each other 26 miles, in a *north-east and south-west* line, the pitch of the strata is 108 feet, an average of four feet per mile.

3. Between Stations A and I, which are distant from each other 22 miles in a *north north-west and south south-east* direction, the descent of the same beds is 96 feet, an average fall of four and one-third feet to the mile.

4. Between Stations O and M, the latter of which is distant from the former 42 miles in an *east north-east* course, the fall is 163 feet, or very nearly four feet to the mile.

5. Between Stations O and B, distant from each other 35 miles in an *east and west* line, the descent is 41 feet, which indicates an easterly dip of a trifle more than one foot to the mile.

6. Between Stations P and F, separated by an interval of 30 miles in an *east and west* direction, the descent is 12 feet towards the east, which gives an average easterly dip of about five inches to the mile.

Attention has already been called to the possible errors in Nos. 4, 5 and 6.

An examination of the facts above enumerated, and a comparison of them with others of like nature, which the map renders possible, seem to justify the following conclusions:

1. There is scarcely any appreciable east or west dip in the uncovered portions of the upper beds of the Cincinnati Group. Accepting Dr. Locke's elevations above named as accurate, a slight easterly dip is established, but of less than one foot to the mile. Using only those elevations obtained by the present Survey, a surprising evenness of this horizon is shown in an east and west direction. The facts obtained from the Artesian Well at Columbus, indicate a strong easterly dip of these beds in the interval between Springfield, for example, and Columbus, but it has scarcely begun in the region which we are now considering.

2. The only appreciable dip is northerly, and generally varies between the limits of 3 and 5 feet to the mile. Sometimes, for short distances, it exceeds the latter figure even, but through the longer ranges it does not generally go beyond 4 feet to the mile.

B. The consideration of the date of this uplift, especially as shown by its relations to the surrounding and overlying formations, is the only topic that remains to be discussed.

In the first place, it may be remarked that all of the facts known in regard to the Cincinnati Axis, go to prove that it was of very slow and gradual formation. It was a gentle flexure of the earth's crust, involving the Lower and Upper Silurian, and, to some extent, the Devonian

formations of Ohio. To the southward, its emergence as an island in the ancient sea was probably of earlier date than in Ohio, just as in southern Ohio its emergence was earlier than in the northern part of the State. Thus different portions of the geological series of this general region have been involved in the different stages of its history. As has been already suggested, there is a measure of probability in the view that this movement of elevation was synchronous with certain great movements of depression on the eastern border that have come to be recognized in the explanation of the geological phenomena of that part of the continent. Such views, however, can only be counted *probable* in the present state of our knowledge.

More definite testimony upon the date of this emergence is furnished by the various formations that have grown around this axis as a nucleus. The discovery of a conglomerate in the Clinton Limestone of Highland county, which is recorded in the report on that county, is a fact of great significance. The interpretation given in the report referred to, is the only one admissible, viz: that when this conglomerate was formed, the uplifting of the Blue Limestone region had already begun; that early in the Clinton epoch, land lay to the westward of the present limits of Highland county; that pebbles were worn where the shore line broke the sea, which were solidified again as a calcareous conglomerate in the deeper off-shore waters to which they were borne.

The thinning of the Clinton Limestone, as it is followed from the northward, is another fact that can best be explained by connecting it with this upward movement of the sea-bottom. In Greene county it has a thickness of 40 feet; in Montgomery county, at the Dayton quarries, it never exceeds 16 feet, and in the southernmost outliers shrinks even below this measurement.

Other members of the Cliff Limestone suffer a like diminution as they are followed towards the axis. The Helderberg Limestone of Highland county furnishes a striking example of this sort, shrinking from 100 feet to 15 feet in the course of 2 miles, in included sections, and disappears from the scale entirely at other points.

The failure of the Corniferous Limestone entirely, south of Fayette county, is another of the same line of facts. All go to show the prolongation and gradual elevation of this fold, the process of elevation having lasted through several of those vast cycles of years that make up geological periods.

As in all similar movements of the earth's crust, the history of which we can trace, there were alternations in the action of the uplifting forces that were here at work, the land that had been formed being carried

down beneath the sea in long continued submergence, as is attested by the heavy deposits that must be referred to such periods of depression. The Niagara series, that overlies the Clinton, would seem, both in its heavier and its lighter sections, to require for its explanation such a downward movement. The only unequivocal example of this kind in South-western Ohio is, however, furnished by the line of junction of the Huron Shales (Black Slate) and the underlying limestone. These shales overlie, in some instances, the Corniferous Limestone, as at Columbus; in Ross county and southward they overlie the Helderberg Limestone; while at a few points in Highland county they rest directly upon the Niagara Limestone. The last two limestones must have been elevated above the sea when the Corniferous Limestone was in process of formation, but a subsequent movement of depression carried them down to be covered alike with deposits of the Huron Shales.

From the foregoing facts, we seem warranted in drawing the following conclusions:

1. The Cincinnati axis in southern Ohio, was raised above the sea at the end of the Blue Limestone period, or certainly early in the history of the Clinton epoch.

2. It underwent various oscillations, but the elevatory movements exceeded those of depression.

3. The rate of the movement was exceedingly slow, as is attested by the gentle slope of the strata that have been elevated—by the want of any anticlinal fracture in the Cincinnati beds, at least, and especially by the fact that formations separated from each other as widely as the Cincinnati Group and the Huron shales, are both involved in it.

The question has often been asked, whether the anticlinal arch of Cincinnati formerly contained the various members of the Cliff Limestone of Ohio in their order, overlain, perhaps, even by the shales, sandstones and coal measures that make up the geological scale of this and the adjoining States. To this question, the facts here adduced enable us to give a distinct answer in the negative. The conglomerate bands and thinning edges of these higher formations, as they are followed towards the axis, show very clearly that their strata were formed around an insulated nucleus.

The Cincinnati section, proper, was originally crowned, there is little reason to doubt, with the Lebanon beds in whole or in part. The denuding agencies to which these regions have been exposed in the enormous periods that have elapsed since they were added to the dry land of the globe, are certainly sufficient to account for a vast amount of erosion. In fact, the preservation of so much of these old deposits is rather the

source of difficulty than the disappearance of the cap of the arch, and of the beds which once filled the valleys of to-day, even though these eroded portions make an aggregate of hundreds of cubic miles in Southern Ohio.

The more prominent features of this formation have now been briefly touched upon. They will, however, be still further elucidated in the following reports upon those counties of south-western Ohio in which the Blue Limestone can be studied to best advantage.

In these reports, however, attention will not be exclusively given to the bedded rocks of the districts considered, but the geological history contained in their drift formations and topographical features, will be also noticed. And inasmuch as several of the leading topics to be treated can find abundant illustration in each one of these counties, it has been deemed proper to distribute them among the counties reported upon, on this wise:

The discussion of the *upland drift beds* and *upland soils*, will be treated with more detail than elsewhere in the report on Clermont county.

The *deposits of the Ohio Valley* will be discussed under the geology of Hamilton county.

The *structure and history of the Great and Little Miami Valleys*, respectively, will be taken up in the reports upon Butler and Warren counties.

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CHAPTER XIV.

GEOLOGY OF HAMILTON COUNTY.

The geology ot Hamilton county, the south-western corner of Ohio, will be treated of, under the following heads:

I. Topography.
II. Bedded Rocks and their economical products.
III. Drift Deposits, or Surface Geology.

I. The prominent topographical features of Hamilton county, are shown in the accompanying map, in which the surface is divided into two main divisions—viz: *highland* and *lowland.*

The first division embraces all the higher table lands of the county, which have a general elevation of 200 to 500 feet above low-water at Cincinnati. All of these areas, though often covered with superficial drift deposits, are underlain with bedded rock which is everywhere easily accessible, and which impresses peculiar features upon the face of the districts that contain it.

To the second division, are referred the valleys of the county, and not only those which hold the present rivers, but also those in which no streams of considerable size are now found, but which are due to the eroding agencies of an earlier day. Both of these classes of valleys are often filled with heavy accumulations of drift, but they agree in being destitute of bedded rock except at the levels of the streams they contain, or, as is often the case, at considerably lower levels.

The thickness of the drift beds does not generally exceed 100 feet, and thus it will be seen that in the Ohio Valley, the lowlands represented on the map have a maximum elevation of 100 feet above low-water at Cincinnati; but as we follow back the Miamis and the lesser streams, we find these beds assuming higher elevations, as the floor of the country

that sustains them is gradually elevated, so that they sometimes attain, in the northern and eastern portions of the county, a height of 150 or even 200 feet above the same base.

In other words, the highlands of the county are the areas in which the bedded rocks remain to an elevation of 300 feet and more, above the Ohio River, while the lowlands are those areas from which the rocks have been removed, at least to the levels of the existing rivers and lesser streams.

The slopes that connect these two kinds of areas are commonly precipitous, as in the river hills of Cincinnati, but sometimes the descent is broken by the interposition of drift deposits.

The valley of the Ohio, which here runs in an east and west direction, makes the southern boundary of the county, and though deep, is comparatively narrow. Several of the north and south valleys that traverse the county are absolutely wider than the Ohio valley, and when the volumes of the streams that they contain are taken into the account, the disproportion between them and the first named valley, is very great. A similar state of facts obtains through southwestern Ohio—the valleys that trend to the west of north, especially, having been excavated on an ampler scale than the rest, other things being equal. These facts seem to point to glacial erosion as a prominent cause in the production of the surface features of the country, as the glaciers are known by the striae they have left to have advanced from the northwest.

An examination of the map of the county in the light of the facts already noted, will serve to show what an acquaintance with it will abundantly confirm, that its surface has suffered a vast amount of erosion. The most interesting facts in this connection are not the valleys which are occupied by the greater streams of to-day, but those deep and wide valleys that are at present either entirely deserted by water-courses, or traversed by insignificant streams, wholly inadequate to account for the erosion of which they have availed themselves. Attention will be called to one or two instances of this sort.

The broad valley now occupied in part by Mill Creek, and in part left entirely unoccupied, extends continuously from the present valley of the Great Miami at Hamilton, to the Clifton hills, just north of Cincinnati, where it divides into two branches—one passing to the north and east of the city and entering the valley of the Little Miami, between Red Bank station and Plainville—while the other branch, the present valley of Mill creek, passes directly to the Ohio on the western boundary of Cincinnati. No rocky barriers, nothing in fact but the same drift terraces that make

the walls of its present course, shut out the Great Miami from entering the Ohio valley at the same points where the Little Miami and Mill creek now enter. Indeed there is the best of reason for believing that it has followed in the past mutations of its history these very courses to the great valley. Mill creek has taken possession of the middle portions of this valley, but has never occupied but one of its lower branches, and that one the narrower.

The most striking examples of this erosion of an earlier day are to be found, however, on the western side of the county, and are, for the most part, to be referred to the same river whose agency has already been invoked.

There is an open cut, at least two miles wide, in the north-eastern part of Crosby township which bears due westward from the present course of the Great Miami river. Near the west line of the township, this old channel is deflected to the southward, and is thenceforward occupied by the Dry Fork of Whitewater, until it is merged in the valley of this last named river. That the streams which hide themselves in this great valley to-day, have really had next to nothing to do with its excavation, is evident from the fact that there is not one of them whose course agrees with the direction of the valley, but all cut across it tranversely. More than half of the townships of Crosby, Harrison and Whitewater, have been thus worn away and made to give bed to the rivers in the successive stages of their history. The channel above named can be confidently set down as another of the earlier courses of the Great Miami.

Still a third of these old channels, more interesting in some respects than either of the two just named, is found near Cleves, Miami township. By reference to the map, it will be observed that the river here approaches within a mile of the Ohio, but instead of entering the great valley at this point, it makes an abrupt detour to the west and south, and only reaches its destination after a circuit of 10 miles. Its approach to the Ohio at Cleves is blocked by a ridge that is interposed, 150 to 175 feet in height. A tunnel that was carried through this ridge, in the construction of the Whitewater Valley canal, and which is at present used by the Indianapolis and Cincinnati Railroad, shows it to be composed of glacial drift. The direction of this channel is in the line in which the glaciers advanced, so that its existence can be quite plausibly ascribed to these great agents of denudation. Whether or not the origin of this channel can be referred to the glacial period, its closure was certainly effected then.

It tasks the imagination to account for the excavation of these broad and deep valleys by existing erosive agencies, even when they are rein-

forced by the important addition of glacial ice, but to agencies identical with these, the work must be referred. There is no evidence, as has already been shown, of minor flexures or axes of disturbance in the Blue Limestone region, by which the strata could have been thrown into hills and valleys, but on the contrary, the beds are found to occur in unbroken regularity, being affected only by the slight general dip of which account has been previously given. It is scarcely necessary to say that opposite sides of valleys give every possible proof of having been originally continuous, the sections which adjacent exposures furnish being absolutely identical in their leading features.

The Cincinnati Group has been found to demand for its original formation long continued cycles of peaceful growth and deposition, and in like manner the fashioning of its beds into the present topographical features of the country, must have been in progress through such protracted ages that the historic period in comparison shrinks into insignificance.

Strictly speaking, there are no hills in Hamilton county, the surface being all referable to the table lands and to the valleys worn in them. What are called the Cincinnati hills, for example, are merely the isolated remnants of the old plateau, which have so far escaped the long continued denudation. Indeed the highlands of the county are all of them outliers or insulated masses, surrounded on every side by the valleys of existing rivers, along the deep excavations wrought out by these streams at an earlier date and under somewhat different geographical conditions. These islands of the higher ground vary in area between quite wide limits, some of them containing a few scores of acres and others as many square miles.

The high ground immediately appertaining to Cincinnati, furnishes a good example of these outliers. By reference to the map, the insulation of this high ground will be seen to be perfectly effected by the Little Miami valley, the Ohio valley, the Mill creek valley, and the abandoned channel of the Great Miami, already described, on the northern and eastern sides. Very important consequences result to the city from this insulation. It follows, for instance, that there are but two natural ways of ingress to the city by lowland, or, in other words, that there are but two railroad routes possible—one by the Ohio valley, and the other by the Mill creek valley. Both of these are circuitous, and, in other respects, unfavorable, especially as ways of approach from the east. These difficulties have led to the project of reaching the business center of the city by a tunnel from the northern valley.

The Dayton Short-Line railroad, now in process of construction, encounters, near West Chester, one of these outliers in its route, which

necessitates a grade of 45 feet to the mile at this point, the highest grade, in fact, on this line (New York Central) between tide water and the Ohio river.

Another very noticeable outlier is found a mile west of North Bend. The Ohio and Mississippi railroad skirts it on the Ohio valley side, while the Indianapolis and Cincinnati road passes to the north of it, through the old glacial channel which has already been described.

II. The bedded rocks of Hamilton county have been already described in the account given of the Cincinnati section, for this section exhausts the scale of the county, the upper division of the Blue Limestone or the Lebanon beds never having been found within its limits. No repetition of the statement previously given, is necessary in this place, but a few additional facts, bearing chiefly upon local details of structure and contents, can be appropriately introduced.

The River Quarry beds do not constitute a marked feature, in any respect, of the geology of the county. There are but comparatively few points where these strata are exposed. A moderate amount of building stone of superior quality is taken from the Covington quarries, opposite Cincinnati. But little of the rock in this portion of the series can be burned into lime, but the concretions, so abundant in many of the beds, constitute a hydraulic lime of great energy.

The second element of the Cincinnati section, viz., the Middle or Eden Shales, is as much more prominent than the first in the county, as its greater extent in the vertical scale would lead us to infer. It is, however, mainly found in the slopes of the hills, as it is not firm enough in structure to resist denuding agencies, when unprotected by the higher series. Very few products of economical value are derived from this part of the scale. Indeed, its relations to economical interests are mainly in the way of disadvantages to be overcome. These disadvantages result directly from the nature of the materials of which these beds are composed. It will be remembered that in the 250 feet now under consideration, not more than one foot in ten is limestone, the remainder being soft shales, clays or soapstones, as they are variously designated. These shales have scarcely tenacity enough to hold their place in steep descents when acted on by water and by ice; still less when they have been removed from their original beds, can they be made to cohere; and they thus form treacherous foundations for buildings erected on them or for roadways constructed in them.

The city of Cincinnati, in many of its building sites, streets and approaches, encounters these disadvantages, which can only be overcome by increased outlay in the way of foundations. These facts are most

plainly shown in the approaches to the city from the east by the Ohio valley, frequent slides occurring along the steeper slopes of shale in which streets and dwellings are involved. Gilbert avenue, now in process of construction through Eden Park, also suffers from its geological location, and will require large expenditure to give it stability along this line.

Nearly all of the smaller streams that are bedded in these shales show contortions and flexures of their strata that have resulted from the slipping of the higher beds into the valleys.

The third division, viz., the Hill Quarry series, which makes the upland of the county, is by far the most important of the three, in the areas it covers and the products which it furnishes. The summits of the insulated masses already named, belong to this division, and constitute about three-fourths of the surface of the county. Most of the quarry stone of the county is also derived from this source. The Cincinnati quarries have thus far been vastly more important than those of any other district; but as the hills within and adjoining the city limits are being occupied for building sites, it will result that railroad transportation will be invoked, and when it comes to this, the more desirable building stone of the cliff formations from adjoining counties will come into competition and be more largely used.

It may be noticed here that it is chiefly due to the fact that so large an amount of quarrying has been done about Cincinnati, that this particular locality has become the classic ground in the way of fossils that it now is. The numerous and ample exposures gave to the earlier collectors unexampled opportunities—opportunities which are not likely to be repeated. It seems hardly possible that such a collection of Blue Limestone fossils will ever again be collected by one man, as that made within the last fifteen years, by C. B. Dyer, Esq. Many of the most interesting localities of fifteen years ago are now covered by permanent buildings, and every year diminishes the available areas.

A few localities, principally in the vicinity of Cincinnati, will here be named, in which some of the rarer fossils can be found:

Triarthrus Becki	Taylor's creek, Newport, Ky.
Heterocrinus simplex	Baldface creek, Sedamsville.
Climacograpsus typicalis	" "
" "	Crawfish run.
Fusispira subfusiformis	"
Lichenocrinus crateriformis	"
Strophomena gibbosa	"
Trinucleus concentricus	River banks, Covington, Ky.
Conularia Trentonensis	" "
Lichenalia concentrica	" "
Orthis emacerata	Anderson estate, Clifton.

The waste of the Hill Quarries furnishes, however, by far the larger proportion of the admirable fossils of this locality. Scarcely any exposure of it in the county has failed to yield choice forms of the various groups represented here.

III. The Drift Formations of the county are naturally divided into two groups, corresponding to the main topographical features of the county already indicated, viz.:

1. The drift deposits of the highlands and slopes.
2. The low land or valley drift beds.

1. Drift deposits cover the highlands of Hamilton county with but very limited exceptions. Towards the southern boundary, these beds are light, measuring but few feet (4–10) in thickness, and as already intimated, areas are occasionally found from which these deposits are altogether absent—the shallow coating of soil found in such areas being native or referable to the decomposition of the limestone that has been bedded here.

There is a good degree of uniformity among these high level drifts, and the distinction between them and the native soils, indeed, is not always very manifest. The presence of rounded pebbles of Blue Limestone and of northern rocks, in the drift beds, though often but very sparingly distributed, is the best means of distinguishing these beds from the native soils. The drift clays are certainly derived in large part from the waste of Blue Limestone, effected in their case by glacial attrition, while the native soils have the same origin, except that the work of disintegration has been done in their case by the slow action of the atmosphere. The agreement between the drift soils of these southern counties and the native soils which are met here, is closer than is found between native and foreign soils in most sections of the state. This seems to be accounted for by the fact that a large area of the same formation lies north of them, which the glacial sheet was obliged to traverse and denude before striking upon this region. The Blue Limestone of these counties is thus largely covered with Blue Limestone waste.

The average thickness of these upland drift beds falls below 20 feet, but occasionally heavier sections are found. In the northern part of Sycamore township, in the vicinity of White Oak school house, a high drift ridge occurs in which 20 feet of surface clays are underlain with a deposit of fine yellow moulding sand. This stratum, when filled with water, is a quicksand, and renders wells impossible, or at least very difficult to secure. But little clean gravel occurs in the uplands of the county, and boulders also are infrequent.

The yellow surface clays sometimes overlie a few feet of tough blue boulder clay, filled with scratched and striated pebbles, apparently the product of the melting glacial sheet. This is not, however, by any means a constant element in the section.

In short, the upland drift of the county is not as varied and interesting as that of the regions immediately to the northward, or even to the eastward. The slopes show the same characters in their drift beds that have been already described, except that the deposits are generally heavier.

2. The second division, or the lowland drift beds of the county, are, in their characteristic formations, of much later date than the deposits already discussed. These deposits can be classified in their superficial aspects, under two principal divisions, viz.: (*a*) the bottom lands; (*b*) the terraces or second bottoms.

These divisions are distinguished from each other, not only by their different elevations, but also by the different materials of which they are composed—the terraces being largely composed of gravel, with occasional beds of sand and clay, while the bottom lands contain in all cases a greater proportion of fine materials.

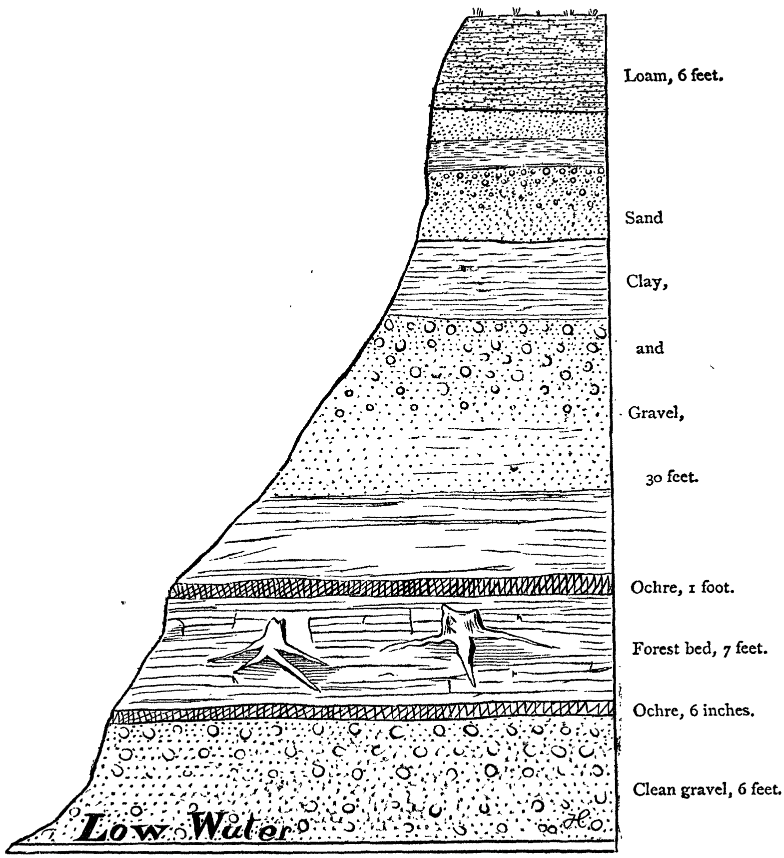
Of the upland drift, no general or typical section was given, for the reason that, aside from the monotonous deposits of yellow clay, there is no uniformity in the order in which the different formations occur; but in the case of the division now under consideration, it is possible to represent in a single section the more important facts that are to be observed. The deposits of the Ohio valley, it will be remembered, are to be especially considered in this report.

A section is here appended, taken at Lawrenceburg, Ind., which gives the general structure of the Ohio bottom lands more clearly than any exposure met with, strictly within the limits of the county.

Beginning at low water, we find the deposits that make up the river bank, arranged in the following order (ascending):

6.	Brick clay, covered with 1–2 feet of soil	6 feet.
5.	Sand, gravel and loam	30 "
4.	Ochreous sand	1½ "
3.	Carbonaceous clay, an ancient soil	7 "
2.	Ochreous sand	½ "
1.	Clean gravel	6 "
		51 feet.

Section of Ohio River Bottoms, Lawrenceburg, Ind.



The elements of this section will be noted in their order. The first of them, six feet of gravel, is, perhaps, the least constant of the series, being sometimes substituted by some of the clays of the drift. The gravel of the Ohio differs from that of the Miamis in being largely composed of sandstone pebbles instead of limestone. It is, consequently, much less durable than the river or bank gravel of the Miami districts, and this fact, taken in connection with the difficulty of access, withhold it generally from applications to road making.

The second, third and fourth elements need to be taken together, as they are closely connected in their history. The point to be noted in regard to them, is the constant occurrence of a stratum of carbonaceous clay between two seams of ochreous gravel. The clay is quite heavily charged with vegetable matter—much of it in such a state of preserva-

tion that it can be readily identified—and other portions again intimately intermingled in a fine state of sub-division with the substance of the clay. The trunks and roots of trees—some of the latter *in situ*—twigs and branches, layers of leaves, ripened fruits, grasses and sedges, are all clearly distinguishable. Several of the species of trees can be determined, some by their wood, others by their leaves and fruits. Among them may be named: *Platanus occidentalis* (Sycamore); *Fagus ferruginea* (Beech); *Carya alba* (Shell bark hickory); *Aesculus glabra* (Buckeye); *Juniperus virginianus* (Red Cedar).

A cucurbitaceous plant, probably *Echinocystis lobata* (Wild Balsam apple), is also shown to have been abundant by its seeds, which are preserved in the clay.

The leaves frequently occur in layers several inches thick, and are very like the accumulations that are now left in eddies of the river by freshets or floods. The deposits of the river at present always have an elevation of at least 20 feet, and sometimes even of 40 feet, above the bed now under review.

The constant occurrence of *vivianite*, or phosphate of iron, in this deposit, is to be noted. Its presence, indeed, is an invariable characteristic. The mineral is usually found in small grains, but sometimes it replaces twigs and leaves and other vegetable growths. The quantity in some portions of the beds is considerable, amounting sometimes to 2 or 3 per cent. of the whole deposit. In such cases it imparts its color to the mass, and thus justifies the name by which it is known—"blue earth."

Several apparently trustworthy accounts have been received of the discovery of the bones and teeth of the mastodon and mammoth in this deposit, but these and all other mammalian remains are of very rare occurrence. It is possible that the "chips" and "axe-marked" stumps reported at various points in excavations in the drift beds, attest the former presence here of the gigantic beaver, now extinct—*Castoroides Ohioensis*. It was certainly a tenant of the state during the general period to which this old forest bed must be referred. That its work upon trees might easily be mistaken for axe-marks, will need no proof to any one acquainted with the work of the existing species of beaver.

In a few instances, land and fresh-water shells have been found in the clay, sometimes in quantity enough to convert the clay into a shell-marl.

This stratum is shown at all points along the valley in which bottom-lands occur. Its elevation above low-water varies from 5 to 20 feet. It is generally covered superficially with the waste of the overlying banks, but even in such cases, it reveals its presence by the long lines of wil-

lows and other vegetable growths that establish themselves upon its outcrop. Two things conspire to adapt it especially to the growth of vegetation. In the first place, it is an impervious stratum, and turns out the water that descends through the overlying loams and sandy clays, thus giving to willows and other plants of like requirements, a constant supply of moisture; and secondly, this stratum, as has been already intimated, is in reality an ancient soil, having been carried at an earlier day through the processes of amelioration, by which beds of sand and clay are fitted to support vegetable growths.

There are, however, many points where the force of the current in high water uncovers these beds, and where consequently good sections are always offered. Excellent disclosures of them are found at New Richmond, Clermont county, and also at Point Pleasant, on the Kentucky shore. The spring flood of the present year, 1872, has furnished an unsurpassed exhibtion of this formation at the mouth of the Little Miami river. Rafts of tree-trunks are shown at all of these points, though the wood generally perishes very quickly when exposed to the air.

That this very interesting stratum has so long escaped observation, is probably due to the fact that it could so easily be referred to the agencies that are now at work in the valley. When the trunks of trees and layers of leaves belonging to it, have been noticed in the banks of the river, it has naturally enough been supposed that they are the deposits of earlier floods, agreeing as they do with the materials transported by the floods of our own time. But in describing the Lawrenceburg section, now under consideration, as the general section of the Ohio Valley deposits, it has already been shown, at least by implication, that this explanation is inadmissible. The extension of this sheet of carbonaceous clay under all the various drift deposits of the valley, as is shown by very numerous natural and artificial sections, proves that it is of earlier date than these overlying deposits, and the character of this stratum shows that it has a very different history from that which these higher deposits record.

It is, perhaps, still too early to write out this history in its minuter features, but the facts already given show us that we have in this sheet of blackened clay, the bottom lands of the Ohio valley at an earlier day, and indeed under very different conditions from those that now prevail. The river then ran in a channel lower by 40 feet at least than that which it now holds, and the great valley was then empty of the immense accumulations of sand, clay, loam and gravel, which constitute its bottom lands and terraces to-day.

The various vegetable growths with which this stratum is filled, are to be regarded as largely the production of the soil on which they are now found. There is no other satisfactory mode of accounting for the particular kinds and enormous amount of vegetable matter traced here.

The ochre seams above and below this ancient soil seem to point to marshy conditions that were brought in with the changing levels of the valley. Of the two, the upper seam is the more constant.

As to the particular stage of the Glacial Period to which this buried soil is to be referred, it can be said that there are some good reasons for believing it to be synchronous with the ancient soil, of which such abundant traces are found in the upland drift of southern Ohio, and to which attention has already been invited in the reports on Montgomery and Highland counties. The synchronism which is suggested need not, however, be carried further than to assign both of these carbonaceous deposits to that great division of the drift that is coming to be clearly recognized in both Europe and America, viz: *the interglacial stage.*

This last but not least perplexing chapter of Geological History—the Glacial Period—is receiving in our day a large measure of attention; and in regard to its great outlines, it is easy to note a growing accord—an accord which amounts to substantial agreement among the leading authorities in this department of science. The following three-fold division of Glacial time may be considered to be demonstrated:

1. An age of general elevation of northern land, accompanied by intense cold and the formation of extensive continental glaciers.
2. A general depression of the land with the return of a milder climate.
3. A partial re-elevation of the land and a partial return of a cold climate, productive of local glaciers and icebergs.

The second of these divisions, or the interglacial stage, like each of the others, indeed, must have had an immensely long period for the accomplishment of the work which we are obliged to refer to it. In an early portion of its extended duration, the soils and vegetable growths and ochre-seams of both valley and upland, are to find their date. During its later ages, when the land had suffered a much greater depression, these earlier bottoms were covered with the beds that remain to be described.

In the Lawrenceburg section we find 35 feet (30–50 in the general section) of sands, gravels, clays and loams, which constitute the Ohio bottoms, as the term is generally used. There is no fixed order in the alternation of these materials, except that the surface portions have, for a few feet in depth, a tolerably uniform character. The soil of the bot-

tom lands is quite homogeneous in constitution, and has obviously been formed by the subjection to atmospheric agencies of just such material as it now covers. Beneath the soil, and extending to a depth of about 15 feet, beds of yellow clay occur. The proportions of sand mixed with the clay vary somewhat, increasing towards the lower limit named, and below this the beds consist rather of sand than clay. The beds of clay above named furnish an excellent material for brick-making. The supply of the Cincinnati market is almost entirely derived from this horizon. The great depth of these brick clays, and their entire freedom from pebbles, render a very economical manufacture of brick possible.

Below this limit, sand and gravel and streaks of loam are met, without regularity of arrangement. Of the 15–20 feet intervening between the bottom of the brick clays and the summit of the buried soil, the larger part consists of gravel. The gravel of this horizon is seldom clean, like that described at the level of low-water, but consists of large sized sandstone pebbles, 4–6 inches in diameter, mingled with finer materials.

An equivalent of these beds, but of local occurrence, is the fine-grained clay which was described in the report on Montgomery county, under the name of "Springfield clay." It never occurs in extensive sheets, but is quite limited in vertical and horizontal extent. The heaviest accumulation of it observed in Hamilton county, is in the city of Cincinnati, on North Pearl street, above Pike. It has a thickness there of more than 30 feet, as has been ascertained in the excavations for the foundations of buildings. It has been turned to account in its different exposures for different purposes; at Miamisburg, for the manufacture of paint; at Springfield, for the manufacture of "Milwaukee brick;" the clay being rich in lime and poor in oxide of iron, and thus burning white, while a new use has been found for it in Cincinnati. It was successfully employed in preparing the floor of the new reservoir, its fineness of grain and consequent toughness fitting it admirably for this purpose. It must have been accumulated in eddies or protected areas, during the later ages of the period of submergence.

b. The Gravel Terraces occupy a higher level than the formations already described. The terrace on which Cincinnati stands may be taken as a fair example of them all. Its altitude above low-water varies from 100 to 120 feet, the average elevation being 108 feet. It is composed of distinctly stratified gravel and sand of varying degrees of fineness and purity. The gravel stones are all water-worn. In weight, they seldom reach ten pounds. The upper tributaries of the Ohio supply the materials in part, but a much larger proportion in the vicinity of Cincinnati

is derived from the limestone rocks of western Ohio and the crystalline beds of Canada. The proportion here to be noted among the smaller sized pebbles is, of 10—

5—Upper Silurian and Devonian Limestones.
3—Lower Silurian, least worn.
1—Granitic.
1—Sandstones, &c., of the upper Ohio.

Occasional seams of clay loam occur, but seldom of extent or tenacity enough to constitute reliable water-bearers. Less frequently met, but still constituting a noteworthy feature of the gravel terraces, are seams of bituminous coal, in small water-worn fragments.

The terraces overlie, as will be seen, the formation previously described. Few sections are carried deep enough to reveal the lower beds, but the leaves and wood of the buried soil are occasionally met at considerable depth, and usually, on this account, they attract attention. The following general order of materials will be observed in passing from the surface of the terrace to low-water:

	FEET.
Soil	2—5
Gravel and sand, with seams of loam	40–60
Brick Clay with sand and loam	20–30
Buried Soil, with trees, leaves, &c	5–10
Gravel and clay	5–10
	72-115

The leading facts in the structure of the terraces, show that their history is not to be explained by the present conditions of the continent. They must have been formed under water at a time when the face of the country held a lower level than it now does, by one hundred or more feet. They thus bear direct testimony to two of the most surprising conclusions which the study of the Drift period has furnished to us—viz: that the continent sank during the later stages of this period, considerably below its present level, and that it was afterwards re-elevated.

There is one other line of facts in connection with the drift beds of the county that must not be omitted here. It is the great depth which some of these deposits have been found to hold below the present drainage of the country.

The series of facts obtained by Timothy Kirby, Esq., in boring a deep well in Mill Creek valley, at Cumminsville, and kindly furnished by

him for the use of the Survey, proves very interesting in this as well as in other respects.

Beginning at an elevation of 90 feet above low water of the Ohio, a succession of drift deposits was penetrated until a depth of 60 feet below low water was reached, the bedded rock being first struck at a depth of 151 feet below the point of beginning.

The accompanying diagram represents the section here found :

	Feet.	
	12	Soil and Brick Clay.
	4	Sand.
	34	Blue Clay with Gravel.
	19	Gravel.
	3	Coarse sand.
	11	Sand with fragments of bituminous coal.
	9	Blue Clay with Gravel.
Low water of Ohio river.		
	16	Blue Clay. Fine Sand, sprinkled with coal.
	43	Sand. Water-worn Gravel. Blue Clay with occasional fragments of bituminous coal.
	151	*Shales of Blue Limestone Group.*

Several remarkable facts are to be observed in this section, the most striking of which is the great depth to which the excavation of Mill creek valley was formerly carried. The bed of the stream that occupies the valley to-day is at a higher level by 120 feet than that of the ancient channel. It is easy to see that this erosion could not have been effected under existing conditions. It can only be explained by a higher altitude of the continent, and is thus referred to the opening division of the glacial period. It has not been demonstrated that continuous channels exist at this great depth, but the rocky barriers that fringe the streams

CHAPTER XV.

GEOLOGY OF CLERMONT COUNTY.

Clermont county is bounded on the north by Warren county, on the east by Brown, on the south by the Ohio river, and on the west by the Ohio river and Hamilton county.

TOPOGRAPHY.

Its surface consists essentially of a table land, which has an elevation of about 500 feet above low water of the Ohio. This plateau is bisected from east to west by the very tortuous channel of the East Fork of the Little Miami river, which is cut down, in the central regions of the county, to a depth of more than 200 feet below the general level of the table land. The surface descends quite precipitately on the south into the Ohio valley, and much less abruptly on the north and west into the Little Miami valley.

The drainage of the county, effected by the East Fork, is considerably more important than that which finds its way to either of the larger streams just named. Indeed this stream constitutes the most marked topographical feature of the county. After the streams already mentioned, Stone Lick, a tributary of the East Fork, comes next in importance. Obanion creek, which drains the north-eastern portions of the county to the Little Miami, has also considerably modified the surface of the districts which it occupies.

The tributaries of the Ohio that take their rise in the county, are of quite limited extent, and have wrought out deep but narrow valleys in their rapid descent. The larger of these streams show no rock in their lower reaches, their channels having apparently been cut below the present level of the valley when the country stood at a higher elevation above the sea.

There are no very striking examples of erosion in the county outside of the great valleys already noticed, and in regard to these valleys, a

remarkable contrast is to be observed between Clermont and Hamilton counties. This latter district has been traversed by the great drainage channels of western Ohio for long continued ages, and a vast amount of its rocky substratum has been carried away, but Clermont county has not suffered from such ravages. On its western boundary, near the junction of the East Fork and the Little Miami, there are a few square miles mainly occupied by gravel terraces at present, which show the eroding agencies of the rivers in earlier stages of their history. The village of Milford is located upon an island, or insulated mass of Blue Limestone, being surrounded on every side by deep channels of erosion. The Little Miami now flows to the west of the town through a comparatively new channel, as is attested by its rocky boundary, but its course before the Drift Period lay to the north and east of the town, and the confluence of the two streams was then effected there. A single example of an ancient, drift-filled channel of the East Fork was also noted three miles above Batavia.

But although the more conspicuous examples of this agency are wanting in Clermont county, proofs everywhere abound that water has been at work in shaping the surface through periods of great duration. Insignificant streams are found in broad valleys, and other such valleys occur which are entirely untenanted.

It may be said in a general way, that the table-land of the county has a remarkable evenness of surface. One portion of it can be seen to excellent advantage along the line of the Cincinnati and Georgetown turnpike, which traverses the whole breadth of the county on the highlands between the Ohio and East Fork valleys. The notes of a recently conducted railroad survey along this line have been kindly furnished by the chief engineer, Paul Mohr, Jr., of Bantam, from which it appears that the summit nearest to the western boundary of the county has an elevation above low-water of the Miami, near its mouth, of.........497 feet.

Summit near Withamsville..496 "
" " Bantam ....465 "
" " Bethel. ....490 "

The north-eastern districts of the county are part of an extended tract which takes in portions also of Warren, Clinton, Brown and Highland, the surface of which is almost a dead level, and which originally constituted an area of white oak swamps. Most of these swamps have now been drained, but the descent from them is so slight in many cases, that in times of abundant rain they revert to their original condition. There are many localities in which the water can be taken with nearly equal facility in different directions. These flat-lying tracts of Clermont county

constitute, however, only the border of this extensive region, and do not exhibit its characteristics in their most pronounced forms.

GEOLOGICAL SCALE.

There are some points of special interest in connection with the bedded rocks of Clermont county. In the first place it holds the lowest rocks of the State, and secondly, the main axis of the Cincinnati Group, about which all the western and central portions of Ohio are built, passes through it.

It will be remembered that in the discussion of the Cincinnati Group or Blue Limestone formation, a three-fold division of the beds that compose it was made, viz., in descending order:

3. The Lebanon beds, 300 feet in thickness.
2. The Cincinnati beds, 425 feet in thickness.
1. The Point Pleasant beds, 50 feet in thickness.

All of these divisions are shown in Clermont county. The last named division, or the Point Pleasant beds, is found only here. It consists of 50 or more feet that underlie the lowest rocks exposed at Cincinnati. The dip of the Blue Limestone beds is mainly to the north, and consequently the southward trend of the Ohio valley, as it is followed upwards from Cincinnati, brings up to view layers successively lower than any that occur in the river quarries of the city. There is probably also a slight westerly dip from the central or eastern portions of Clermont county, which conspires with the northerly inclination to bring these lower beds to light. The consequence is, that from the vicinity of New Richmond to the eastern boundary of the county, 50 or more feet are shown, that lie below low-water mark at Cincinnati. As an admirable section is furnished in the Point Pleasant quarries, the name of this locality is affixed to this division of the rocks.

This section furnishes the most desirable building stone of the Blue Limestone series. Mention has already been made of the fine architectural effects that are being secured in and around Cincinnati, in the use of this stone as building material. The best of these results have thus far been attained with stone quarried from these lowermost courses. It dresses more easily than that derived from the hill quarries, and it possesses a better shade of color, combined with a general exemption from the weathered seams that disfigure the higher beds. Quarried, as it is, at the water's edge, river transportation enables it to enter the city markets with advantages at least equal to those possessed by the home

quarries. The trade is rapidly extending, and many thousands of perches are carried annually to Cincinnati.

A little above low-water mark, at Point Pleasant, a heavy concretionary bed is found that is not only useless for building purposes itself, but that also obstructs the work of quarrying the true building stone. Analysis seems to indicate that this layer, in part or in whole, can be made into an excellent article of hydraulic cement. In laboratory experiments, at least, a very energetic cement is produced from it. Several hundred tons are annually unearthed at the Point Pleasant quarries alone. The products of this and other similar concretionary layers at various points along the river, would need to be collected in case an effort should be made to turn them to economical account.

It is scarcely necessary to add, in concluding the account of this division, that the Point Pleasant beds furnish no other exposures than those already indicated, viz: immediately above low-water in the Ohio valley, between New Richmond and Chilo.

The Lebanon beds are found in Wayne township, in the north-easternmost corner of the county. Exposures involving 50 or more feet of this series, occur along the head-waters of Stone Lick, but the only interest connected with its presence here, is that which belongs to it as a new geological horizon.

All the rest of the county, which is so nearly its whole area that it seems scarcely worth while to make any exception, is underlain by the middle division of the Blue Limestone or the Cincinnati beds proper. Of this series an ample exhibition is made in Clermont county. The uppermost stratum of this section, the heavy bed of Orthis biforata, which occurs in the Cincinnati hills at an elevation of 425 feet above low water, makes the surface layer of all the higher tracts of the county, with the exception of the single township already noted. If the higher beds of the series were once here, it is certainly remarkable that so much of the county should be weathered or worn down to this exact horizon.

The elevation at which this bed occurs in Clermont county has already been mentioned, being greater than at Cincinnati by 50–75 feet. The conclusion drawn from this fact and others of similar import, will also be remembered, viz: that the summit of the Cincinnati arch is to be found in the central or eastern portions of Clermont county.

DRIFT.

The Drift deposits of the county constitute a very interesting feature of its geology. It may be said in general terms that the whole county is covered with these deposits. The only exceptions to be noted are the

slopes of the hills, principally the hills that border the Ohio valley, which are often covered with native soil, or soil derived from the disintegration of the underlying rocks. The bottom lands and terraces of the greater valleys, which must be referred to the later stages of the Drift period, will be treated by themselves, the deposits that occupy the Ohio valley having been already discussed under the geology of Hamilton county.

The drift formations proper, of Clermont county, consist almost exclusively of clays. These clays often contain imbedded pebbles in considerable quantity, but there are next to none of the heavy accumulations of clean sand and gravel that make so important a feature in the high level drifts of the regions immediately north. Thin veins of sand are, however, intercalated, especially with the deeper clays. The drift beds vary in thickness from 1 to 50 feet. There are several well-marked districts in the county, with each of which a nearly uniform thickness of these deposits is found. In the north-eastern portions of the county, viz., in Goshen and Miami townships, the average thickness on the uplands is about 10 feet, and it is seldom that the depth exceeds 20 feet, while in the eastern, central and southern central regions, the drift beds average 20 feet in thickness, and a total depth of 50 feet is sometimes found. In the southernmost townships, again, there is a progressive thinning of the beds as we approach the river, until upon the brink of the river hills, these drift clays seldom measure more than 5 feet, and often shrink to 2 feet in thickness. When the all-important relations of this drift covering to the county are considered, constituting, as it does, its soil and determining its water supply, it will be seen that its thickness is an element of no little consequence. The minimum thickness is generally sufficient for the necessities of the soil, but the nature of the water supply varies with its varying depths.

It may be remarked in passing, that very little of the water supply of Clermont county is derived from springs. Neither its bedded rocks nor its drift formations are favorable to their production. The clearing of the swampy uplands has cut off the supply of summer-water from many of the smaller streams, so that the supply for man and beast must now very largely be artificially procured. In the region of the shallower drift beds, the dependence is mainly and increasingly upon cisterns, while in the regions where the heavier beds prevail, a good supply through wells is generally possible. It is true that in the first region named, wells are often sunk into the underlying rock, but the same peculiarity of constitution that makes springs in the Blue Limestone infrequent or impossible, viz., the intercalation of beds of impervious shale by which the

surface water is excluded, renders these strata equally unprofitable as water bearers for wells. When a permanent supply is reached in such wells, however, as it sometimes is, the water is often so largely charged with lime and salt, as to be but poorly adapted to human uses. The presence of these same mineral impurities, with the addition of oxide of iron, renders the water, which is derived from the drift beds proper, in some instances unfit for use, and in many cases, to some extent, unwholesome. There is no question that properly constructed cisterns furnish by far the safest and most healthful supply for much the largest portion of the county. The subject has not yet received general attention at all in proportion to its importance.

The general elements of the upland drift of Clermont county, are the following, named in descending order:

4. *Surface clays*—generally *white*, sometimes blackened by swampy conditions, entirely free from gravel, from 1 to 8 feet in thickness.
3. *Yellow clays*—abounding with gravel, with occasional boulders, often constituting the surface instead of No. 4. Thickness seldom exceeds 10 feet.
2. (a) *Forest soil*—a stratum of carbonaceous clay, containing vegetable matter, as leaves and wood, with occasional beds of peat, and in some districts replaced by (b). *Bog iron ore bed*—a seam of ochreous clays that pass into true ores, yielding over 40 per cent. of metallic iron. The last division ranges from 1 to 2½ feet in thickness, the former sometimes rises as high as 8 feet. Both divisions are sometimes absent.
1. *Blue boulder clay*, or hard-pan, with occasional layers of sand intercalated, resting upon the rocky floor of the county.

These elements will be briefly characterized in their true order.

1. The bowlder clay or hard-pan, is found very generally but not universally, in the northern and central regions of the county. It is shown in many of the natural sections that are furnished by the streams, and in such artificial sections as are carried to sufficient depth. It is covered by varying thicknesses of the remaining members of the series. Where the total depth of the drift beds reaches 20 feet, a full half of the section generally belongs to the bowlder clay. It cannot be confounded with any other formation in the districts in which it occurs. It is composed of dark blue, fine grained and tenacious clay, holding imbedded polished and striated pebbles and bowlders. Most of the pebbles are derived from the Blue Limestone formation, though frequent representatives of more distant rocks are found. Many fragments of Blue Limestone are scratched and polished on their sides, but their edges are still unworn. The bowlders belong almost without exception to the crystalline and igneous rocks, that are found *in situ* only to the north of the

great lakes. Specimens of northern ores, iron, copper and lead, are sometimes, though rarely, met with. The occurrence of *gold* in the bowlder clay and in the gravels derived from it, is a matter of considerable theoretical interest, and seems never to have attracted the attention which it well enough deserves. Gold-bearing rocks have been but rarely detected among our northern erratics, and indeed none are known to be reported in the great Arctic region, from which all these erratics have been brought, at least in the central portions of the continent. The gold of Nova Scotia has, however, been referred to the same general horizon which these rocks occupy. But there is certainly gold in the bowlder clay of southern Ohio. It can be gathered in flakes from the surface of the clay, and "panned" in "colors" from the gravel derived from the clay. The total amount cannot be insignificant, but the percentage certainly runs very low. The working of beds of clay and gravel which have had such a history as our drift formations as gold-bearing deposits, is, of course, preposterous, but just this has lately been attempted in Clermont county. A few years since, the "Clermont county Gold Mines" attained a short-lived, neighborhood and newspaper notoriety. One or two thousand dollars in cash, and more than this in labor, were expended in ill-judged schemes, without other results than bringing into circulation a few scores of dollars worth of Clermont county gold. The general dissemination of geological knowledge, makes it every year more difficult to gather money to be spent in such visionary projects.

From what has already been said, it will be seen that Clermont county has no monopoly of the gold-bearing formation of Ohio. This formation should be named the "Drift gold field," rather than the "Clermont county gold field." All of the counties of south-western Ohio certainly share in its treasures, and, without doubt, one locality is as good as another, where gravels are found that have been washed from the bowlder clay. The best results thus far known to have been attained in gold mining in Ohio, are reported from Warren county, where, in one day, gold to the value of \$6.00 was obtained by an outlay of \$10.00; a half dozen days' work being also thrown in. The practical interest connected with the gold of the bowlder clay is confessedly very small, but, as already intimated, the theoretical interest is by no means inconsiderable. It may be possible, by following back the lines of glacial transport, to reach a belt of gold-bearing rocks at present unknown.

The bowlder clay of the county is frequently traversed by veins of yellow clay, which are arranged as if due to molecular attraction, but it is possible that they are to be explained as lines of weathering which has followed down the joints of the clay.

The bowlder clay is the main water-bearer of all the districts in which wells are practicable. Mention has already been made of veins of sand in connection with the bowlder clay. There is frequently a foot or two of sand directly overlying its upper surface, and its substance is never free from irregularly distributed beds of the same material. These sand beds constitute the water veins of the regions to which they belong, and must always be reached if water is obtained in permanent supply. The water in them seems often to lie in sheets of considerable extent, rather than in narrow channels.

The surface of the bowlder clay is a horizon of springs, generally weak ones, along the valleys where sections of the drift are made deep enough to show it. In Stone Lick township, near Charleston, there are good exhibitions of it. A spring that comes out upon its surface there, on the land of G. W. Boutell, has supplied the country around, for one or two miles, in times of drought.

The origin of the bowlder clay will not be discussed at length in this place, but it may be remarked, in passing, that there is every reason to believe that we have, in this unique formation, the materials that were gathered in and under the continental glacier that is known to have covered the northern portions of the continent, in the earliest or glacial stage of the drift period. As the icy sheet disappeared, under the advent of a warmer climate, the bowlder clay was left to cover the regions from which it retreated.

It may be added, in conclusion, that this division of the drift beds is shown much more frequently and unequivocally in these southern counties, upon the very margin of the upland drift formation, than it is to the northward, where a far heavier section is shown.

2. The next element of the drift is one of great interest in southern Ohio generally. It consists, in Clermont and several adjoining counties, of two sub-divisions, as has already been stated, viz: (*a*) the Forest Bed, an ancient buried soil; (*b*) the Bog Iron Ore Bed.

These two very frequently coexist, a layer of ochreous gravel representing section (*b*) in connection with the buried soil, but in the extensive white oak swamp that begins upon the eastern limits of Clermont county, the first division generally disappears, and the second becomes more prominent. The first division has already been discussed, in the reports upon the Geology of Highland and Montgomery counties, and the proofs were there given that the blackened clay and loam which we find buried, associated with leaves and branches and trunks of trees, really constitute an ancient surface of the land, a surface that was converted into a soil, covered with forest growths and tenanted by animal life.

No further mention will be made of this division here, except to say, that it is abundantly represented in Clermont county. There is no better exhibition of it to be found in southern Ohio than is furnished in several square miles of Tate township, in the vicinity of the village of Bethel. The land lies high, its elevation above low water of the Ohio being 500 feet. The drift beds show an unusual thickness here, a depth of fifty feet having in some instances been reached without finding bedded rock. All the wells that are dug throughout this area, pass through the buried soil, as the water-vein lies immediately underneath it. It is found at a depth varying from fifteen to twenty-five feet. The section of the drift beds contains the following beds:

20 feet—	Yellow clay, with beds of sand and gravel.
4 "	Fine-grained clay, free from grit.
2 "	Forest Bed.
20–30 "	Bowlder clay.

The line of demarcation between these different elements is generally very distinct. The fine-grained clay, overlying the forest soil, is probably the "Springfield clay."

The second of these sub-divisions, the seam of ochre and bog ore which replaces the buried soil in a portion of the county, seems to have thus far escaped attention. It is found, as has been said, through all of the flat-lying region that begins in the eastern townships of Clermont and stretches through Brown to the middle of Highland county. It consists of ochreous clay holding 10–15 per cent. of iron, that passes into a heavy bog ore which yields over 40 per cent. of metallic iron. The thickness of this stratum is generally 2–2½ feet. It is covered by 6–8 feet of whitish clays, and is shown in all the slopes of the shallow valleys that are found here. A specimen taken from the farm of Samuel Moorhead, Jackson township, yields the following results (Wormley):

Specific gravity	2.735
Water, combined	11.00
Silicic acid	22.40
Iron, sesquioxide	59.60
Alumina	3.20
Manganese	1.60
Lime, phosphate	0.26
Lime, carbonate	0.48
Magnesia	trace.
Sulphur	0.00
	98.54
Metallic iron	41.72
Phosphoric acid	0.12

This, it will be seen, constitutes an iron ore of average quality. The sample analyzed represents a considerable amount of the formation. Specimens can be found, exceptionally rich, that would doubtless yield a somewhat larger percentage of iron. It has not yet been ascertained just how large a proportion of ore the two feet of the deposit would yield, but the limits will probably be found between 10 and 20 per cent. The iron mines of Clermont county, like its gold mines, seem therefore likely to possess more scientific than economical interest. Both belong to the drift formations of the county, but they are doubtless separated from each other in their history by many thousands of years. The gold was derived from the crystalline rocks of high northern latitudes, and transported here by the great glacial sheet that invaded the state in the opening ages of the Drift Period; the iron ore was accumulated where we find it, in the interval of depression that followed the Glacial Epoch, when the area to which it now belongs was a stagnant marsh or shallow lake. Microscopic plants were doubtless the agents by which the iron was extracted from the waters that held it in solution. After its deposition it suffered molecular change and consolidation to considerable extent. It is easy to see that all this involves a long history. While the ochre seam was slowly accumulating here, the margins of the marsh, and the drained uplands generally, were covered by an abundant vegetation, which was carried at length beneath the floods by the continued subsidence of the continent. To the interval of depression that followed, must be referred the remaining members of the drift series of the county, Nos. 3 and 4. It is certain that these white and yellow clays both belong to the same general division, but it cannot perhaps be made out that they are exactly synchronous, or that they have precisely the same history. Each will be briefly characterized.

3. The yellow gravelly clays which divide with the white clays, No. 4, the whole upland surface of the county, are seen in every township, and often for many adjoining square miles. They furnish the soil of a large part, probably one-half, of the county. They are called yellow clays, as their weathered portions always have a yellowish shade, but the unweathered beds are often described as gray clays. The pebbles that in part compose them are not water worn, but often retain the scratched or polished surfaces referred to glacial action. Bowlders are comparatively infrequent. It is rare to find one of more than 300 or 400 pounds weight. The largest one measured in the southern portion of the county, was on the land of Col. Perrine, in Bethel. The diameter of this block is 4 feet. They grow scarce to the southward, but are not wanting in the highlands that border the Ohio.

The yellow clays do not show any distinct marks of stratification, except in the occasional seams of sand and gravel that they contain. The surfaces of the level tracts that they occupy, are almost always made up of one or two feet of whitish, fine-grained clay, free from gravel. This superficial covering is certainly in large part due to the agencies of plants and animals. Plants are constantly bringing up finely divided mineral matter from the subsoil and leaving it upon the surface. A ripened leaf sometimes contains a tenth part of its weight as mineral matter or ashes. But many tribes of animals are far more efficient than plants in the transfer of these materials. Earth-worms, ants, crawfish, and various sorts of beetles are constantly bringing fine particles of earth to the surface. The aggregate of such agencies as we see around us now, cannot be insignificant. These agencies would scarcely need to be continued a thousand years to account for the surface covering of the yellow clays.

4. The last element of the series is identical in character with the surface clays just described, except that it is not derived from gravelly clays that underlie it. It is found only in the low-lying tracts to which the ochre beds belong. Its thickness is generally more than five feet, and less than ten feet. It is homogeneous in character, except that its color changes as we descend, to yellowish, with streaks of blue clay. The subsoil when exposed, however, soon becomes as white as the surface.

The general composition of the white clays is shown in the following analysis of a Highland county sub-soil, from the district now under consideration:

Sub-soil from Buford, Highland County.—Wormley.

Water combined	5.54
Silicic acid	62.60
Alumina	18.90
Sesquioxide of iron	6.30
Manganese	0.20
Phosphate of lime	0.63
Carbonate of lime	1.89
Carbonate of magnesia	1.82
Potash and soda	2.32
Total	100.10

The general section of the drift in the white clay districts can be expressed in the following terms:

	FEET.
{ White clay	1–2
{ Yellow clay, weathering white	6–8
Ochre bed	2–2½
Bowlder clay	10–20

The last of these beds, the bowlder clay, abounds in scratched and polished pebbles, but the upper clays are entirely destitute of pebbles through the 5 to 10 feet that compose them. There are many square miles in continuous tracts upon which not a pebble can be found.

Water is generally borne upon and in the bowlder clay, but the supply is often inadequate and the quality is almost always poor. The tenacity of the subsoil, makes of all these tracts what is commonly called *crawfish land*. The untitled portions of the country are everywhere dotted with the mounds of white clay, brought up by the fresh-water lobsters as they deepen their subterranean chambers to follow downward the slowly descending sheet of water.

Large areas of black land are also included under the white clays, as it is easy to see that the former are simply the white clay lands, transformed for a few inches of their surface beds, by the abundant addition of vegetable matter.

The origin of these last named elements of the drift section of the county, will not be here discussed. It is obvious, however, that the white clays, No. 1, of the above named series, must have been deposited from water. Their fineness of grain and homogenous constitution, cannot be otherwise explained than as a result of the materials that compose them having settled in comparatively quiet waters.

SOILS.

In concluding a discussion of the high level drift beds of Clermont county, a few remarks will be added upon its upland soils, and the system of agriculture to which they are subjected.

The soils of the county are naturally divided into two general classes ;

1. Native soils, formed *in situ* from the decomposition of the Blue Limestone rocks ; and
2. Drift soils, derived from transported materials.

1. The first division has a very limited extent, being for the most part confined to the steeper slopes of the river hills, and especially of the hills that border the Ohio valley. The color of such soils varies with the proportion of organic matter incorporated with them, those having least, being reddish. They are always possessed of great fertility, and produce year after year the most exhausting crops without apparent deterioration. Trees thrive with especial luxuriance upon these slopes. There are, however, some disadvantages to set over against so great ex-

cellencies. The slight depth of soil makes tillage difficult, and heavy showers are liable to remove the whole surface of acres to a lower level in an hour.

2. The Drift Soils will be no further sub-divided than in the preceding pages, where they are classed as yellow and white clays.

The yellow clays differ but little from the native soils, as they are formed weathering of the drift, which consists so largely in this region of Blue Limestone waste. Clermont county, may, therefore, by way of excellence, be styled a Blue Limestone county. More than any other district of the state, it shows in its soil the characteristics of this formation. The great adaptation of its surface to fruit growing, seems connected with its origin and composition. This county produces more peaches and small fruits than any other county in the state, and, indeed, the only part of its agricultural interest that is really prosperous at present, is that which is connected with fruit-growing. Its highest uplands that slope towards valleys to the west of them, are best adapted to this purpose, as such stations in south-western Ohio seem to enjoy the greatest immunity from spring frosts.

A valuable growth of forest trees has covered the uplands of Clermont county. The species most commonly found on the flat-lying tracts are the following, named in the general order of their abundance :

Quercus palustris	Swamp Spanish oak.
" alba	White oak.
" macrocarpa	Burr oak.
" discolor	Swamp white oak.
Acer rubrum	Red or swamp maple.
Fagus ferruginea	Beech.
Ulmus Americana	Elm.

The various other species indigenuous to southern Ohio are shown on the native soils of the hill sides, and on the slopes and the bottom lands of the great valleys.

The yellow clays produce wheat of excellent quality, but are not as naturally adapted to the growth of Indian corn.

The soils of Clermont county are suffering exhaustion to an alarming degree, under the system of agriculture to which they are subjected. The universal testimony is, that the production of the staple crops per acre has shrunk, within the last 25–40 years, full 50 per cent. The truth is, that the raising of these staples is no longer pursued with profit in Clermont county, as is evident from the fact that the average yield of wheat on all the yellow clay lands, is less than eight bushels per acre, and of corn, under thirty bushels per acre.

The white clay lands are in even worse condition, as their physical constitution puts them at a great disadvantage, their fine-grained and tenacious beds, unless skillfully managed, turning to sun-dried bricks. What both kinds of soils especially require, is the abundant incorporation of vegetable matter, but no contribution of this kind is made to them. The analysis of the white clay sub-soil, given upon a previous page, shows a remarkable amount of the phosphates and alkalies to be present in it, a general constitution, as far as chemical elements are concerned, that fit it to become one of the finest soils of the state. Instead of this, it is very generally stubborn and sterile, reluctantly yielding a scanty subsistence to those who live upon it. The districts, however, that are blackened by the addition of organic matter, show, by their great superiority, what the soil most urgently needs.

There are many examples of good farming to be met with in Clermont county. The fruit-growing interest, in particular, is in the main skillfully managed, but nothing in agriculture can well be worse than the system generally followed. That it may not seem invidious to speak of the agriculture of one county in these terms, it may be added just here, that the system is precisely the same that is pursued in Warren, in Butler, in Hamilton counties, in all of southern Ohio indeed. The happier constitution of the soils of these above named counties, puts further off the evil day to which all must come at last that adopt a system of spoliation in agriculture. An utter disregard of the fundamental laws of this great science is everywhere seen. Barnyards are drained by spring-branches, wherever it is possible to so locate them that they can be. Straw and corn-stalks are burned upon the fields; fattening stock is often fed in the highways. Clermont county, finding the raising of grain no longer profitable, is now supplying the Cincinnati market quite largely with hay. If the hay-wagons come back empty from the city, there is no risk in prophesying that a few years will see the end of this line of production, for all experience shows that nothing depletes a country more fatally than the removal of its grass crop without any return.

In conclusion, it may be said, that though the soil of Clermont county is now suffering incipient exhaustion, it is still within the resources of a rational system of agriculture, whenever the guidance of such a system shall be invoked, to restore and maintain its lost fertility. It still contains an untold amount of agricultural possibilities.

There is certainly no material interest of the district now under consideration that more imperatively demands a general and thoughtful examination than that which concerns the treatment of the soil. The subject lies at the very foundation of the public prosperity. There is no hope of the amend-

ment of our present evil ways in this regard, except through an intelligent comprehension of the questions involved. Of fundamental importance among these questions is that which relates to the origin of soils. But the origin of soils is a geological question, and can only be approached by the methods which geology employs. And thus we come to see that certain phases of geological inquiry have as definite and vital a concern for the agricultural interests of south-western Ohio, as other lines of geological investigation have, for the coal and iron lands of the State.

do not at least disprove this theory, as there is always room for a deeper channel on one side or the other of the great valleys.

Another interesting fact is the occurrence of water-worn fragments of bituminous coal, quite similar to those found in the terraces already noticed. They occur at various depths, the lowest at 140 feet below the surface, and the highest at 80 feet below. These facts, so far as known, stand by themselves, and no explanation is proposed. It is hard to see how the waste of Ohio coal fields should find its way in quantity into Mill creek valley, and there is certainly no other obvious source of supply.

The well from which these facts were obtained, was carried to a depth of 541 feet below the surface. The chips and borings, accurately labeled as to depth, have been turned over to the Geological Survey. Analysis of these specimens will reveal the character of the strata underlying Ohio to a depth greater by about 400 feet than any rocks exposed within the limits of the State. The shales of the Blue Limestone series appear to continue to a depth of 400 feet from the point of beginning.

Carbureted hydrogen gas escaped from the well in considerable quantity from a depth of 280 feet downwards, but no large accumulations of petroleum compounds were indicated.

CHAPTER XVI.

GEOLOGY OF CLARKE COUNTY.

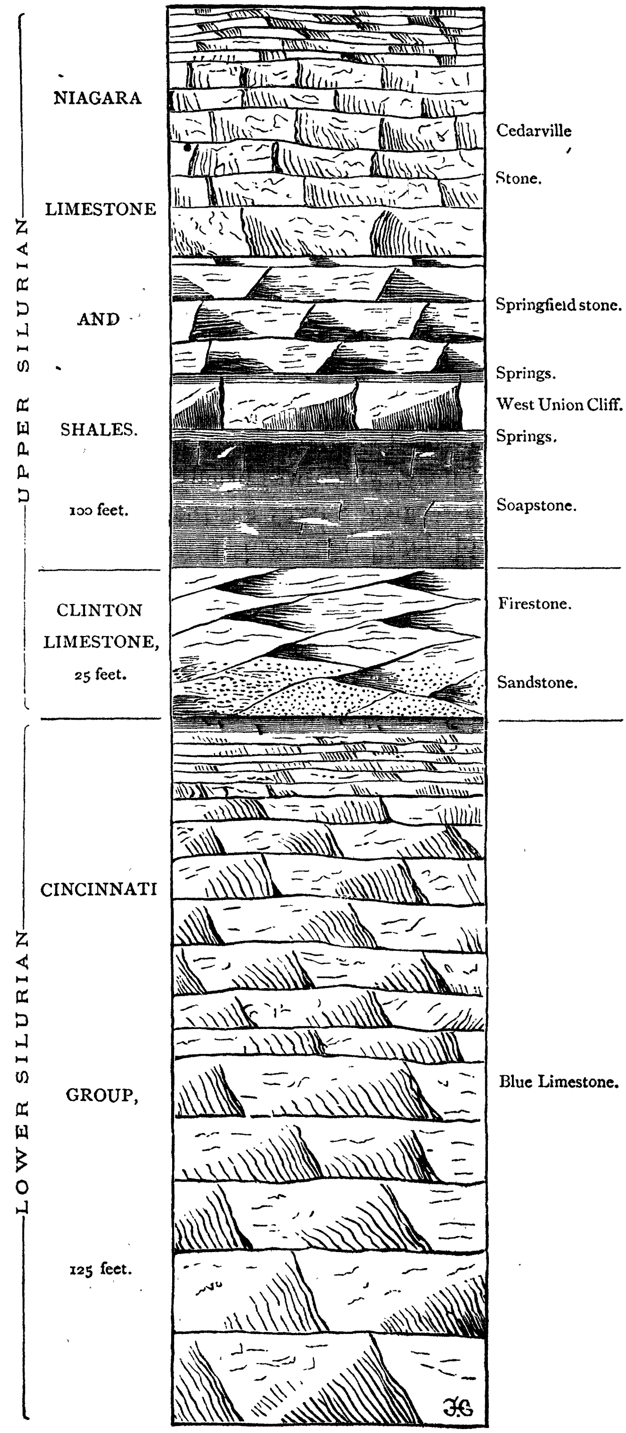
The geology of Clarke county agrees in its main features with the geology of Montgomery county, which was briefly described in the Report of Progress of the Ohio Geological Survey for 1869. Its rock formations are identical with those of Montgomery county, viz: the Blue Limestone or Cincinnati Group, the Clinton limestone and the Niagara formation. It is quite probable that the north-eastern corner of the county is underlain by the Helderberg limestone, the next formation of the state in ascending order, but there are no exposures to show its presence. The argument for its occurrence here is this: a line, drawn to connect the nearest northern outcrop of this limestone with the nearest exposure to the southward, would traverse the north-eastern corner of the county, as before observed.

The geological scale of the county is represented in its composition and extent in the accompanying diagram.

The lowest land of the county is found in the valley of Mad river, in the south-western corner of Mad River township. It is about 325 feet above low water mark of the Ohio river, at Cincinnati. From this lowest level, taken as a floor, the whole county is built up to the extent of 100 feet, with the uppermost beds of the Blue Limestone or Cincinnati Group. The average thickness of the Clinton limestone, the next story of the county, does not exceed 25 feet, and the heaviest single section of the Niagara group gives 75 feet in addition to these measurements. The deposits of the drift formation are built up in many instances from 75 feet to 100 feet above the rocky floor.

The highest land of the county, then, is from 600 feet to 625 feet above low water mark at Cincinnati, or from 1,025 feet to 1,050 feet above tide water. Some isolated points may exceed even this elevation by a few feet. The summits of Pleasant township have, probably, as great an elevation as any land in the county.

Geological Series of Clarke County.



Excluding for the moment the drift beds from consideration, we may look upon the county as having been originally composed throughout its entire limits of three regular stories or formations, the stories being, however, of unequal height. The Blue Limestone once formed the floor of the whole county to the height at which we find it now, in those districts where it is overlain by the Cliff limestone. There is a slight inclination of the strata towards the north, it is true, but no account needs to be taken of this fact at present. The thickness of this formation in the county, as has been already stated, is about 100 feet. In other words, the whole area of Clarke county has been occupied with the uppermost beds of the Blue Limestone group, to an extent of about 450 feet above low water, at Cincinnati.

The second story is quite distinct from the first in mineral character and composition. It too was originally spread in beds of uniform thickness over all the county. The second story has, however, only one-fourth of the vertical extent of the first, its average thickness not exceeding 25 feet. It constitutes the lowest portion of the Cliff limestone of the older geologists of Ohio.

The third story, or the Niagara formation, is not of uniform thickness now, and there are some considerations, presently to be added, that seem to show that it was not originally built up with the same degree of regularity that the two previous formations disclose. No average thickness can be assigned to the Niagara rocks. The greatest thickness observed in any one section is 75 feet. There is the best of reason for believing that this too, like the Blue Limestone and Clinton rocks, once occupied the full limits of the county. The accompanying map of the county shows the areas at present respectively occupied by these different formations, it being always understood that no account is made of the drift beds. In point of fact, the drift covers and obscures the rocky floor to such an extent that there is only an occasional outcropping of bedded rock. There are several townships of the county in which the underlying rock has never been seen. It is possible that the Helderberg limestone, which has been mentioned as the next formation of the geological scale of the state in ascending order, and which, perhaps, occurs in the north-east corner of the county, once extended over the Niagara limestone, and thus formed a fourth story. There are some considerations, however, that militate against this view, the principal one of which is, that it is now clearly established that the Cliff limestones of south-western Ohio were deposited around the shores of an ancient island, extending from Cincinnati south-west to Nashville, and which was, for a long series of ages, gradually extending itself above the sea. The area of Clarke county,

probably for the most part, became dry land, in other words, was converted into a part of this Silurian island, before the deposition of the Helderberg limestone. At all events, the rocks of this last named series, now found in Champaign county, a few miles to the northward, give unequivocal indications of having been formed in shallow water and along shore lines, their surface being covered with sun-cracks and ripple-marks. Any person who has visited Urbana cannot fail to have noticed these markings in the flag-stones that are there used.

The proof that the Niagara and Clinton limestones were once extended over all the surface of the county, is clear and conclusive. Outliers of these formations are found, on all sides, beyond the limits to which their unbroken masses now extend. Dispennet's Hill, near Osborne, on the Springfield and Dayton pike, in the extreme south-western corner of the county, is an outlier of Clinton limestone, while directly to the westward of the main line of outcrop of the Clinton rock in the county, are to be found heavy beds of both Clinton and Niagara, in Wayne township, Montgomery county, and in Bethel township, Miami county. Their beds constitute, in fact, a large island of Cliff limestone, the boundaries of which are Mad river, the great Miami river and Honey creek.

The present topography of the county is to be mainly attributed to erosive agencies, which are still in progress. All that is wanting to complete the horizontal plain of rock which originally filled the area of the county, has been carried away by running water. The surface of the county has been worn and chiseled by these agencies to a degree quite beyond a ready recognition, for these channels have been silted up by the drift deposits so as to be greatly reduced in dimensions, or even wholly concealed from view, unless some accidental section exposes them. The present surface of the county is irregular, through a considerable portion of it, the gravels and clays having been left in hills and hollows, but it is certain that the rocky floor has a far more uneven surface. Instances will be hereafter given, in which some of these buried channels have been brought to light by artificial excavations.

It is easily seen that the present features of the county are principally due to the present drainage system. The great valleys are mainly those of the present great streams. An exception is found in the valley of Honey creek, which is indeed much wider than that of the great Miami, into which it opens. It is altogether probable that the Great Miami, in its earlier history, flowed southward by a more circuitous route than it now holds, leaving its present bed near Tippecanoe City, and bearing eastward, by way of New Carlisle and Midway, to the present valley of Mad river. A glance at the map will show how much wider is the valley

that lies here than that which contains the river to-day. No obstruction to such a course will be found in bedded rock, for that has all been removed, and heavy beds of sand, clay and gravel, occupy this great excavation.

The valley of Mad river is the most marked topographical feature of the county. Rising in the island of Huron Shale (black slate), just east of Bellefontaine, its source has an altitude of 1,438 feet above tide water, which is as great as that of any other point in the state. The stream then passes over the edge of the Corniferous limestone, over a considerable outcrop of Helderberg limestone, in Champaign county, and finds its way to Clarke county, over a flat tract of country which is underlain by the Niagara limestone, but at such depth that it is nowhere exposed in the bed of the stream. Swampy borders of considerable extent are found along its course in Champaign and the northern part of Clarke counties, which help to bestow upon the stream its comparatively permanent character. These borders, locally called "cat-head prairies," consist largely of vegetable accumulations, and are peculiarly retentive of moisture. Ditches draw the water but for a very short distance on either side, and therefore it is almost impossible to drain these tracts. This whole region, then, is a reservoir of Mad river. The permanence of this stream, together with its very rapid fall, render it the most valuable mill stream in this portion of the state. It has fallen lower during the last summer (1871) than ever before in its recorded history.

It first strikes the Niagara limestone in the vicinity of Springfield, the northernmost cliffs appearing near Snyder's Mill. From this point, the stream has for the rest of its course through the county, very definite and well-marked boundaries in precipitous walls of Cliff limestone, from 40 feet to 100 feet in height. The present river occupies but a very small portion of the intervals between the cliffs for its channel, but uses most of it for a flood-plain, in its highest stages.

An examination of the appended map will show that the work of erosion has been immense in this south-western portion of the county, as indeed it has been through south-western Ohio generally. No other agency, however, but that of erosion, can be called into account for these features—as the strata lie undisturbed—without any considerable folds or flexures. We see the work of erosion now in progress, but it seems slow and inadequate to explain the great gorges before us, but the cause is true in kind, at least. A more rapid action than the present is, however, not only possible, but in the highest degree probable, if we take into account the wearing agencies of the Glacial epoch and of the floods produced by the dissolution of the glaciers.

The tributaries of Mad river share in the peculiarities that it possesses, in the districts through which they flow. Those that enter the river near Springfield, have wrought out picturesque and beautiful valleys in the Cliff limestone, as, for instance, Buck creek and Mill creek, which crosses the Dayton pike two miles below the city. The configuration of the valley at the junction of Mill creek and Mad river, indicate a long continued history, in which the streams have occupied very different geographical relations from those now to be observed. A solitary remnant of their denuding action is found in a little island of Cliff rock, of three-fourths of an acre in area, that rises 30 feet above the general level in the angle between the two streams.

Almost all of the streams of the county, great and small, have their springs and earlier courses in Drift deposits, with which the state is so largely covered. They flow for awhile, many of them, indeed, through their whole extent, in broad and very shallow valleys, that they have wrought in the surface accumulations of clay and gravel. In such cases, the width of the valleys is greatly disproportioned to their depth. On the eastern side of the county, the descent of a few feet—not more than 25 feet below the general level—brings us to a broad, flat plain, one-half a mile in width, perhaps. A stream of insignificant proportions meanders through the valley, but seems lost in the expanse. Indeed, the single-spanned bridge in the midst of a level tract is often our only intimation that we are crossing a valley. The several forks of the Little Miami, in Green and Madison townships, furnish good examples of this sort. It may be noted in passing, that these broad and shallow valleys constitute some of the finest agricultural districts of the county.

The larger streams, as has been already remarked, have cut down their channels in their lower reaches to the rock foundations. Mad river first strikes the rock at Tremont, but it is not continuously bedded or bordered with rock until it reaches Snyder's Mills. Buck creek, in its descending course, first brings the strata to light at Lagonda. The Little Miami exposes no beds of rock in its upper courses, but at Clifton it comes down to the Niagara limestone, and has there cut a narrow and most picturesque gorge for itself to a depth of 60 feet. Honey creek does not touch the Cliff limestone in its whole extent, but now and then strikes a point of the underlying Blue Limestone in the lowest portions of its course.

Other facts bearing upon the topography of the county will appear in the discussion of the succeeding topic.

DRIFT DEPOSITS.

The Drift formation is by far the most important geological division of Clarke county. It covers with its beds almost every foot of the sur-

face in four or five townships, at least, and shuts out every trace of the underlying rocks; it furnishes all of the various soils that characterize the different sections of the county. This last statement alone, which is applicable to the larger portion of the state as well, fully entitles the Drift to take rank in importance above all other divisions of the geological scale, coal measures and metallic deposits not excepted. The soil of Clarke county is a mine from which vast stores of wealth have already been taken, and which teems with untold agricultural possibilities. It is unnecessary to discuss here at any length the general geology of the Drift period, or to state the various theories that have been brought forward in explication of its phenomena. A brief recapitulation, however, of the leading events in the Drift period, as it is shown in Ohio, is both appropriate and necessary.

1. The remarkable fact has been established by a great mass of concurrent testimony which forbids any other construction, that at the close of Tertiary time, an investment of Arctic ice extended itself over the northern portions of the continent as far south, at least, as the 40th parallel of latitude, forming, in fact, a continental glacier similar to that which covers the face of Greenland to-day, pushing before it all of the weathered fragments of the region over which it passed, planing and polishing the rocky floor of the continent, and grinding both the solid rocks and the loose materials of the surface, into gravel, sand and clay. The advance of the glacier was, in the main, to the southward, but it frequently swerved to the east or west, as can be determined by the direction of the scratches left upon the rocks. These striae in Clarke county bear a general direction of S. 12 E. There is, besides this, abundant evidence of a general south-easterly trend in the transportation of local deposits which can be traced directly to their sources. This period of glaciation must have come on gradually, and have had a long continuance. It is almost certain that it was a period of northern elevation. The elevation of a tract of British America, a few thousands of feet above its present level, would serve to explain a great many of the facts involved in the Glacial period. It is highly probable that astronomical causes conspired with these changes of level of the surface of the earth in causing this advance of Arctic ice, and not less in causing its disappearance at a later day.

2. The second stage of the Drift period, which we can mark in Clarke county, is one that has only lately come to be recognized. It is an interruption of the reign of ice, the intercalation of an epoch of vegetable growth in the otherwise barren deposits of clay, sand and gravel. By a change of climate, at least the southern extension of the glacial sheet is melted, and as a result, the floor of the country is covered with a tough,

compact blue clay, filled with scratched pebbles and bowlders—a deposit always known as "hard pan"—though not the only member of the Drift series that receives this designation. By an exposure of long continuance—of many centuries at least—these stubborn clays are converted into soil, and the vegetable and animal life, pushed southward by the advancing glacier, have returned and established themselves upon it. The soil and its vegetable and animal remains are very frequently met in the artificial excavations of the county, and sometimes in its natural sections.

3. An epoch of northern subsidence follows, in which the face of the country is carried fully 500 feet below its present level. Such a depression would insure a great extension of the northern lakes, and also an invasion of the sea from the Atlantic side and by the Mississippi valley. As the country slowly sank and perhaps as slowly rose, the materials of its surface were quite thoroughly assorted into the beds of sand and clay and gravel, which at present occupy the face of the county. In this period of submergence, the old valleys were to a considerable extent filled, and all the irregularities of the rock surface were concealed. As the continent returned to its present level, the drainage system was adapted to the newly formed surface. This system generally coincides in its leading features with that previously in operation, but sometimes for areas of small extent it varies quite widely.

All of these stages, as has been already stated, are distinctly shown in Clarke county.

The polishing of the rocky floor can be observed wherever the rocks themselves are shown. The cap rock of the Springfield quarries is an unusually soft and friable limestone, at least for the Niagara series, and retains these glacial markings less distinctly than most of the limestones of the state, but in the stripping of the quarries the unmistakable exhibition of this great agency are very frequently shown. The Clinton limestone in the vicinity of Snyder's Station, also preserves these striations very distinctly. Upon the western edge of the county, this action is everywhere shown.

The formation of blue clay, due to the melting of the glacier, is not very often seen in the county. The heavy beds of blue clay found in Pleasant, Harmony, Green and Madison townships, are not to be confounded with the true glacial drift. They belong to the Erie clays of Sir Wm. Logan, and must be referred to the period of submergence. The deposits of this age near Catawba cannot be less than 100 feet in thickness.

The buried soil already alluded to, is frequently met in some sections of the county, more especially on the western side. The blackened clays that compose it are struck in every well in certain neighborhoods. Tree-

trunks and animal remains are less frequently met, it is true, but it is by no means an uncommon occurrence to come upon these old growths at a depth of 20 or 30 feet below the surface.

The beds of yellow clay, of sand and gravel, that mark the next division of the Drift, constitute by far the most important member of the series in Clarke county. With the exception of a few almost insignificant areas, the whole soil of the county belongs to this division. The origin of the yellow clays has already been referred to. When blue clay is exposed to the air, the iron contained in it is raised to a higher state of oxidation, and the color is changed from blue to yellow. Such exposure to atmospheric agencies must have befallen the blue clay in the preceding division of its history, and a true cause is found to account for the transformation of these superficial deposits. The weathering of these same blue clays serves also to account in good part for the sand and gravel, as these beds are heavily charged with sand, gravel and bowlders, which the assorting action above named would serve to distribute according to their present modes of occurrence. The line of demarcation between the yellow clays and the beds it covers, is oftentimes very sharp and distinct, which renders it impossible to explain the yellow clays as due to the superficial oxidation of the blue clays since their last emergence.

Clarke county was during this stage part of an inland sea, or rather of a southward extension of the northern lakes. This period, we see, must have been of long duration. Many facts help us to such a conclusion. The sorting and sifting of materials alone would require long periods, but certain other facts impress upon the mind more forcibly the slow growth of these deposits.

Heavy accumulations of yellow ochre or ochreous gravel constitute one of the normal members of the series. These accumulations cannot have been hurriedly gathered or tumultuously deposited where we find them to-day, but are to be referred to the agency of the vegetable kingdom. Microscopic plants separate the iron from the waters in which it is dissolved, and deposit it in the orchre banks of the Drift. A fine example of these ochreous gravels can be seen on the farm of G.W. Hastings, Esq., east of the city of Springfield, in a cut of the London Branch Railroad.

This ochre is sometimes used as a pigment. The quality is very satisfactory, but the labor entailed by the necessary washing of the gravel, will probably prevent it from displacing the foreign ochres in the market.

Another element of the Drift beds that demands a long process of selection and a slow rate of deposition, is the Springfield clay, as a series of very fine-grained clays may be termed, in which iron is wanting, but

which contain a notable quantity of lime and magnesia, and which consequently become white or cream colored, like the Milwaukee clay, when burned. The finest example of this series now known in the county, and indeed in southern Ohio, is the bank shown in the cut of the Atlantic and Great Western railway, just west of Mad river, and worked as a brick and tile clay for several years, by Peter Schindler, Esq. There are pockets of it in the Drift at very many points in this portion of the State. At Miamisburg it has been ground quite extensively into paint, and at Cincinnati it has been used in forming the concrete for the bottom and sides of the new reservoir. It is peculiarly fine and even in its grain, and its whole character forbids its reference to any hurried mode of deposition. In eddies and in quiet basins of the last submergence, it must have been laid down. The Springfield bed is more than 20 feet in thickness. These clays always belong to the later deposits of the Drift.

The sand and gravel are left over the surface of the country in picturesque knolls and ridges, which add greatly to its natural beauty, and which, in the advantages they offer for building sites and road materials, form no mean element in its desirability for human habitation. These knolls and ridges are not the remnants of more extensive beds that covered the whole face of the country originally, as might be thought at the first inspection, but they were deposited where we find them, and in the same form that they now possess. This is clearly proved by the lines of deposition that their sections furnish. The ridges often enclose basin shaped depressions of small extent, which can be accounted for in no other way than as the results of the original deposition of the surrounding masses. These depressions are particularly noticeable in the northeastern corner of the county, near Catawba.

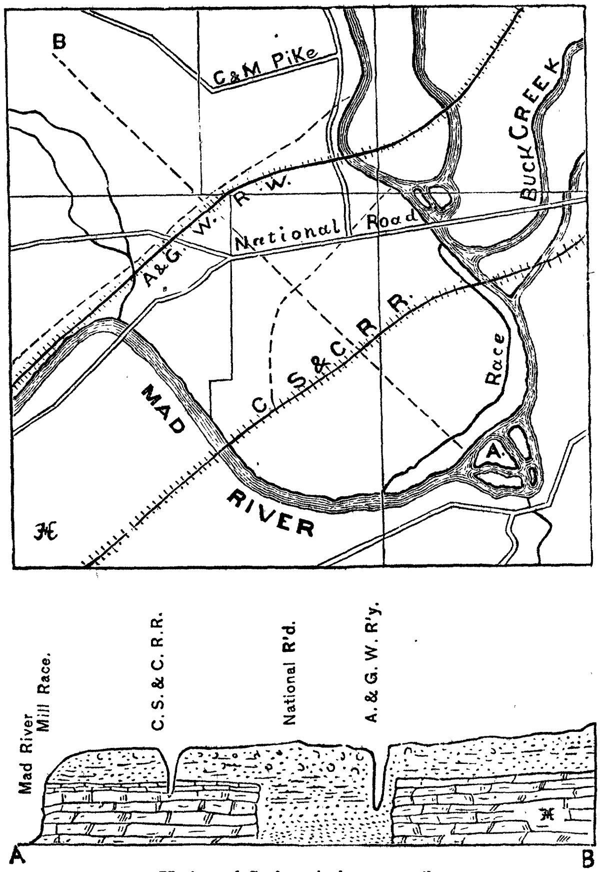
The gravel of the county is largely limestone in its composition, its pebbles representing the two great limestone belts that lie to the northward in the State, viz: the Helderberg and the Corniferous. In the southern parts of the county, the Clinton and Niagara rocks also contribute to its formation, but the Helderberg limestone can be everywhere distinguished as the leading element. Its characteristic fossil, *Leperditia alta*, can be found in almost every cubic yard of gravel in the county. Weathered and worn fossils of the Corniferous limestone are also frequently met. A glance at the geological map of the state shows the quarries whence these vast accumulations have been derived, the Helderberg limestone constituting the surface of at least a dozen counties in the central and northern portions of the State upon its western side. Besides the limestone, there are also great quantities of metamorphic pebbles and bowlders, derived from the granitic rocks of Canada. There

is a wide variety of composition in these pebbles — diorite, granite, quartzite, schist and porphyry being intermingled in the same cubic foot of gravel. The pebbles and bowlders often retain traces of the agencies that fashioned them, in the planed, polished and striated faces that they present. The mechanical violence required to grind the superficial materials of the country, in their various degrees of division and in the proportions in which we now find them, must have been not only vast in quantity, but must have continued its work through protracted ages.

It has already been remarked that, in the period of submergence, the former drainage system of the country had been almost entirely obliterated, in at least its minor features. The old channels were filled with sand and clay; but when, by the last emergence of the land from the waters, a drainage system was again rendered necessary, the surface water selected for its paths of escape the old valleys in the main. It began the work of clearing out the silted channels—work in which it is still engaged, but which it has nowhere yet carried to completion. Sometimes, however, the streams have abandoned their old channels for short distances, and have wrought out new ones. These later formed channels constitute the most of the narrow gorges in the cliff rock that make such a notable feature in the scenery of this region. They are sometimes more circuitous, and sometimes more direct, than the earlier channels. The most striking example of this class of facts is found in the immediate vicinity of Springfield.

An old valley of Mad river is disclosed in the heavy cut of the Atlantic and Great Western railway, from the river bridge westward to Col. Peter Sinz's crossing. A sketch of the course of the river, and also of the railroads that cross it, is appended, by which the facts can be more readily understood. The tongue of land that occupies this bend of the river has an elevation of 100 feet to 125 feet above the level of the stream, and gives no hint in its contour of any break in the rocky floor underlying it. The Sandusky railroad, (C. S. & C.) which was first in order of construction, cuts across this tongue, as will be observed in the figure. A considerable portion of this cut is wrought in solid cliff rock, the maximum depth of the stone cutting being 18 feet. With these facts before them, and guided also by the contour of the land, the Atlantic and Great Western Company, whose line crosses the river half a mile higher and on a grade of 10 feet below the first road, expected also to find rock, and made arrangements for tunneling the hill. The route that they selected, however, chanced to be a buried channel of the river, which allowed an open cut of 65 feet through clay and sand, instead of a rock tunnel. Soundings that have since been made from the track to the level of the river,

Buried Channel of Mad River, at Springfield.



Horizontal Scale, 2 inches to 1 mile.
Vertical Scale, 1 inch to 200 feet.

show Drift materials through this whole extent. The dotted lines in the figure indicate the buried channel, whose general limits can be assigned with a good degree of accuracy from the cliffs that remain, and the soundings that have been made.

It will be observed, that the old channel was much shorter and more direct than that which the river has since wrought out for itself, accomplishing in three-fourths of a mile the same advance that is now gained by two and one-half miles.

The quarries of Springfield and vicinity, reveal numerous examples of a similar sort, old channels being disclosed in the rocky floor, of which the surface fails to give the slightest intimation.

The comparatively recent date of the present river bed of the Great Miami, to the westward of Clarke county, has already been noticed, in connection with the existence of an older course of the river, which, by the peculiarities of the present drainage, has not been obliterated. This older channel follows the present course of Honey creek, turning to the southward in the vicinity of New Carlisle.

There can be no doubt that glacial erosion has done much toward fashioning these valleys, but still we must remember that, in the Lower Silurian island of Ohio, we are dealing with a portion of the oldest dry land of the United States, and the vast length of time in which atmospheric agencies have been at work, demands as a result of their operations, a vast measure of erosive action.

In concluding this subject, it may be remarked, that the rocky floor of the country is exceedingly irregular, full of abrupt declivities and deep gorges, that are either wholly or partly concealed by the Drift deposits.

A brief description of the rock formations of the county comes next in order. These have been already enumerated, as the Cincinnati, Clinton and Niagara limestones.

I. The characteristics of the Cincinnati group, will be given at length in the report upon the southwestern counties of the state, and need not be particularly detailed here. The series always consists of interstratified limestones and shales or clays, highly fossiliferous, and weathering rapidly into soils of great fertility. The characteristics of the series are not prominently displayed in those districts of the county in which the Cincinnati Group is the underlying rock, for reasons already given or readily recognized, the surface in those regions being heavily covered with Drift or alluvial formations. Examination of the map will show these areas to coincide with the deeper valleys of the county.

But few opportunities are furnished in Clarke county to examine minutely the line of junction of the Cincinnati rocks and the Cliff limestone, but from the fact that points of junction have been studied on all sides in the adjacent counties, it is safe to conclude that the order already described as occurring in Montgomery county, obtains here also. A series of non-fossiliferous shales or marlites, from 20 to 30 feet in thickness, oftentimes conspicuously reddened by oxide of iron, mark the closing portion of Lower Silurian time. The astonishing wealth of life that prevailed in the seas in which the Cincinnati rocks were formed, almost entirely disappeared. A few of the more hardy forms survived, and are to be found in the overlying rocks of the Clinton, and even, in some instances, of the Niagara formation. Conspicuous among these fossils, is the bivalve

shell, Orthis biforata or Orthis lynx, which appeared in Trenton time, is found in all the divisions of the Cincinnati group, is met with again in the Clinton, and is finally found high up in the Niagara series. An equally remarkable horizontal range belongs to this fossil, as it is found in the equivalent formations of Europe, and throughout the whole length of the North American continent, from North Devon and King William's Land to Georgia.

II. The Clinton limestone, the lowest member of the formations that were collectively designated the Cliff limestone of Ohio, by the earlier geologists of the West, is shown in very abundant and characteristic exposures in Clarke county. It enters the county in Mad River township, forming the low cliffs that constitute the well defined southern boundary of the valley of Mud run, passing just east of the village of Enon, and crossing Mad river at Snyder's station, where it forms the rocky floor of the railroads, and on the north side of the river showing itself in the low rocky wall that bounds the valley here and forms so picturesque an addition to the scenery, as viewed, for instance, from the Valley pike. After passing just below Donnell's creek, the line of outcrop trends to the north-west, passing through the Funderberg settlement, two miles to the east and north of New Carlisle. From thence it can be followed, though somewhat obscurely, through Pike township, quarries being occasionally worked in it. It is last seen in the Stafford settlement, on the western edge of the county. All along this line, strong springs are found, resulting from the collocation of the porous Cliff limestone and the impervious shales that complete the Cincinnati group.

The characteristics of the Clinton rock in Clarke county, are precisely the same as in Montgomery county, which have been already described. It is always an uneven bedded rock, in its lower portions is of a sandy texture, and is a semi-crystalline, crinoidal limestone in its upper beds. It passes in color from white, through various shades of yellow and red, to a dark, brownish red, which contains a notable proportion of an oxide of iron. The most persistent tint is a delicate pink. The fossils, of which it is so largely composed, are crystalline in structure, and consequently resist the weathering action of the air better than the body of the rock in which they are set. Projecting portions of the fossils are consequently found on all exposed surfaces of the rock, converting them into very beautiful and interesting specimens.

The Clinton limestone is quite uniform in the main elements of its composition, consisting generally of 84 per cent. of carbonate of lime, and 10 or 12 per cent. of carbonate of magnesia. It forms by its disin-

tegration a strong and fruitful soil, as can readily be seen along its immediate line of outcrop. These belts being naturally underdrained by the porous character of the lower beds of the Clinton, and being also abundantly supplied with the elements of plant growth, are very valuable for orchards and general fruit-growing.

Despite its unevenness, it still constitutes a valuable building stone, and is largely used where the more valuable Niagara rock is not accessible. It can be easily quarried, easily dressed, and is as durable as ordinary limestones at least.

Its use as a firestone was noticed in the description of the rock as it is found in Montgomery county. It certainly has the power of resisting, without fracture, the lower degrees of heat to which chimney backs and furnace arches are exposed, and thus adds a valuable element to the districts in which it occurs.

A high degree of heat, however, converts it into a lime, with which good and enduring work can be done. The purest lime in Ohio is derived from the Clinton rocks near New Carlisle. It is burned in considerable quantity by John Brown, two miles west of the village. Its composition has been already given in the previous report, but the fact that it contains over 95 per cent. of carbonate of lime is sufficient to justify the claim here made for it. The comparative values of these true carbonates of lime and the magnesian limestones of the Niagara series, will be treated of in another portion of this report.

The localities at which the Clinton rocks can be observed in the county can be enumerated by the hundred, but one or two will suffice. All of its characteristics can be seen in the exposures at and near Snyder's Station, three miles below Springfield, and also in the cliffs that appear on the opposite side of the river in the line of outcrop already traced. The Herzler and Keifer farms furnish as good examples as any.

III. The Niagara series is, however, by far the most important division of the geological scale of the county. It has a much greater thickness than either of the previously named formations; it covers a much wider area, and furnishes a much more valuable series of products, contributing, indeed, in its lime and building stone, a very important addition to the resources and income of the county. The name of the formation is derived from the remarkable natural section which the Falls of Niagara disclose. The great sheet of limestone that is there cut through can be traced in an almost unbroken extent to the cliffs of Mad river.

The thickness of the series in Clarke county certainly exceeds 75 feet, as a single section affords this measurement without exhausting the series at either its lower or upper limit. As the section to which refer-

ence is made gives the best exhibition of the Niagara group in the county, and as it substantially represents the whole series, a more detailed account of it will be given. It is found at Holcomb's lime kilns, on the Atlantic and Great Western Railway, one mile below Springfield Station. The same section is afforded, indeed, in the cliffs that bound the valley of Mad river for a mile or two above and below this point, but the large amount of quarrying done at Holcomb's kilns, makes it easy to recognize the various elements of the system. If a natural section were to be depended on, that at Sinz's Mill would be found most satisfactory. The elements of the Niagara group at the point named, and in the county at large, are four. They can be named in ascending order—

1. Niagara shale.
2. West Union cliff.
3. Springfield stone.
4. Upper cliff, or Cedarville beds.

The building stone of the county is almost entirely derived from the third member of the series, and the lime from the fourth member.

Brief descriptions of these various strata will now be given:

1. The Niagara shale in Clarke county immediately overlies the Clinton limestone. It will be remembered that the Dayton stone occupies this same position in those portions of Montgomery and adjacent counties in which it is found, but the Dayton stone is an exceptional formation and is confined to quite narrow limits. It seems to have grown in insulated areas of this region on the floor of the sea, while around it, for thousands of miles, calcareous shales and shaly limestones were forming. It must have been deposited in protected basins, in and around which life abounded.

The thickness of the Niagara shales in the county has not been measured with precision, as no section has been found that includes it all, but it cannot be far from 25 feet. This measurement was obtained on the land of Henry Snyder, near Snyder's Station. It will be remembered that in Highland and Adams counties this stratum attains a thickness of 100 feet.

Both forms of the series, viz., calcareous shales or marlites, and shaly limestones are found in the county. In the section already named, viz., at Holcomb's quarries, the *shales* are found, consisting there of a soft, light-blue, impervious rock, 10 feet in thickness immediately above the railroad track. They are locally called soap-stones. The most noticeable feature in their occurrence is, perhaps, the line of springs that comes out

upon their upper surface. A collocation of materials, similar to that which marks the line of junction of Upper and Lower Silurian rocks in southern Ohio, viz., a porous limestone overlying impervious beds, explains the outflow of these springs at this horizon. They are found especially upon the southern sides of the valleys, the dip of the strata throwing the water forward to these outcrops. Examples can be noted along the cliffs that form the southern boundary of the valley of Mad river, from Snyder's Station for two miles northward. One spring of great volume and steadiness breaks out just above the track of the Sandusky railroad, in this vicinity, and would be highly esteemed if it were found where water was less abundant. This horizon is one of great importance in the water supply of the district in which it occurs, not only because of the springs that find their outflow over its beds, but because all of the wells that are drilled through the upper part of the cliff rock must descend to this stratum, in order to furnish a strong and permanent supply. There are some horizons of springs at a higher elevation in the series, it is true, and attention will presently be called to them, but they generally fail in times of drought, and no satisfactory results will be found in wells sunk in the Niagara limestone, unless they are carried as low as the upper surface of the shales. A feeble line of springs shows itself also on the northern side of the valley, and at the very section under review.

In this member of the series, an excellent article of firestone has been found. The furnace arches of the distillery at Snyder's station were several times laid up from it, and better results obtained than any fire-brick then accessible, afforded. Its composition warrants the expectation of its being found a refractory stone, as it is in many instances scarcely anything but a silicate of alumina.

The relations of the shale to the overlying limestone being precisely similar in kind to those occuring at the locality from which this important formation derives its name, viz., Niagara Falls, it is not surprising to find that numerous cascades occur along the margin of the valley. The great cataract owes its continued existence to the fact that its waters pass in their descent over a solid limestone (Niagara limestone) which overlies a shale (Niagara shale). The shale being weathered and removed by atmospheric agencies more rapidly than the solid limestone above it can be worn by the water, the latter formation is left projecting in tables or cliffs, which fall into the gorge below when sufficiently undermined. All of these elements concur in the course of the streams that flow from the table land of the county into the valley of Mad river, where it has been cut sufficiently deep to reach the shales. The locality already noted as showing the springs that flow out over the shale, also

affords excellent examples of the cascades to which reference is here made. Aside from the points now noted, the Niagara shale is but an unimportant element in the geology of Clarke county. It takes no part in the surface formations of the county, as it is without horizontal extension, being found only in the vertical section already described.

2. The second member of the Niagara scale of Ohio is even more insignificant in the section now under consideration, and in the county generally, than even the Niagara shale. Its thickness is but 8 feet in the only locality where it is clearly shown; it yields no products of economical importance; and the fossils found in it are but few and indifferently preserved. Still it is not without its geological interest, as it unequivocally represents the heavy beds of Highland and Adams counties, described by Dr. Locke, in his geological report of 1839, as the "Cliff Limestone" of Adams county, and recognized in the report of the present survey on the "Geology of Highland County," as the "Lower" or "West Union Cliff"—a formation at least ten times as thick in the districts above named as it is here found, and exhibiting in its beds some of the most important facts in the geological structure of this region.

In the section at Holcomb's lime-kilns, this member can be marked as the lowest floor of the quarry. Its contact with the shales is recognized by the line of springs already described, that appears at the junction of these two formations. The rock is massive rather than composed of layers, and is thus ill adapted for building purposes. Nor is it pure enough to furnish a good article of lime. It is to be recognized in but few other sections of the county, and needs no farther discussion.

3. We come next to what has been denominated the Springfield stone, viz: the building stone courses which form so constant an element in the Niagara rocks of Ohio at this horizon. It is separated from the West Union limestone by a distinct boundary. As this portion of the series is so well developed and exhibited in the Springfield quarries, it seems appropriate to designate it as the Springfield limestone, and this name has accordingly been attached to this division in all portions of south-western Ohio in which it is shown. It is a prominent member of the Highland county series, as will be seen in the report on the geology of that county, subserving there the same purpose as a building stone that it does here.

The Springfield limestone is a magnesian carbonate, containing generally about 50 per cent. of carbonate of lime and 40 per cent. of carbon-

ate of magnesia. Some of the remaining substances—a small percentage of silica and also of alumina—stand in the way of its being burned into an approved lime. There is, however, no uniformity in its composition.

The prevailing color of this rock in Clarke county, is a light drab, though several blue courses occur. To the southward, the rock is mainly blue. The desirability of the light colored stone for fine work, is sometimes lessened by faint reddish streaks diffused through its substance.

The thickness of this division is never more than 20 feet, and seldom exceeds 15 feet in this portion of the state. At Holcomb's, it is 13 feet. Like the other members of the series, it expands to the southward, reaching at Hillsboro its maximum in Ohio of 45 feet.

Beginning in the Springfield quarries at the bottom of the series, we find several heavy courses, from 10 to 18 inches thick, overlying the West Union cliff. These lowest courses are blue in color, and despite their massive appearance, are generally treacherous as building stones. Where exposed to the weather, they lose in a few years their dressed surfaces, their seams continually widen, and, in a word, they show themselves to be undergoing a state of certain, though slow, disintegration. The walls of the jail in Springfield, furnish an illustration of all these characteristics. The blue courses generally, even when found above the lowest beds, show the same tendency, and should at least be carefully tested, before being used in structures where they can be attacked by atmospheric agencies. The drab courses are almost all durable building stones in all ordinary situations. Making up as they do the bulk of this division, they furnish an invaluable supply of building stone to Springfield and the adjacent country.

But three courses in the quarry can be raised in large enough tables to make them suitable for cutting. These are, in ascending order, an 8 inch course, a 12 inch course, and a 10 inch course. They are found in the lower half of the section. Of these the middle course is most valuable. Its thickness is sometimes increased to 14 inches. A layer of white, silicious concretions, two or three inches in thickness, lying in the middle of this course, detracts somewhat from its appearance and value, and adds to the expense of dressing. The 8 inch course can easily be split into two 4 inch courses, which are turned to large account in the flagging of the city. The Springfield stone can be cut with very much more facility than the Dayton stone.

The remainder of the series is just as valuable for general masonry as the portion above named. The stone is easily raised, in several of the quarries by the bar alone, in blocks of convenient size and thickness.

The price of the common building stone delivered in the city, ranges from $1,50 to $2,00 per perch. The dressed stone sells for eight or ten times these rates. Not the least among the natural advantages of this thriving and beautiful town is this abundant supply of desirable building stone.

A considerable demand already exists for the products of the Springfield quarries, in the adjacent country, especially in the drift-covered regions to the northward, and this demand is sure to steadily increase. The courses suitable for cutting have already found their way to the Cincinnati market, and make a valuable addition to its resources in the way of architectural supply.

The quarries in Springfield and its immediate vicinity substantially agree in character, when equally advantageous exposures are secured.

The principal dealers in the city at present are Wm. Thompson, George C. Frey, Alexander Mowatt and Petticrew Bros. Below the city, Creighton's quarries have long been worked, and the greater ease with which the stone is there raised, no blasting being required, has enabled these quarries to compete in the city market with those that lie within the city limits. On the western side of Mad river, Col. Sinz's quarries have been opened at a comparatively recent date, and the stone from them is, in some respects, superior to any produced in the neighborhood. The cutting courses have a finer color than in the other quarries, and were they not slightly disfigured by the faint reddish streaks already noted, they would certainly take high rank in any market. The flinty layer found in the city quarries, is either greatly reduced in thickness or entirely disappears.

Still lower, the quarries of Moore and Holcomb, on opposite sides of Mad river, complete the list of the points at which the stone is now raised in large quantity.

The supply is immense, and indeed is practically inexhaustible.

There are two seams of shale interspersed in the series, that constitute sources of springs along the outcrop of the rock. One lies near the bottom of the series, the other at a point three or four feet below the upper limit of the formation. The upper shale also contains very numerous flinty concretions. The more important springs along the valley of Buck creek, belong to one of these two divisions. The wells of the city have sometimes stopped at the vein of water that belongs to the upper seam, but such a supply is precarious, and the drilling should always be carried through to the second horizon, despite any favorable appearances at an earlier point in the descent. It would be safer still to carry the boring to the great sheet of water supported by the Niagara shale, 10 or 12 feet below the last horizon named.

Mention has already been made of the presence of silica in the building-stone courses. This generally occurs in nodules, from two to six inches in diameter, but sometimes in layers of considerable extent an inch or two thick. It is almost always rich in fossils. Indeed it may be considered certain that the silica has, in all cases, been introduced into the rock in the replacement of calcareous fossils. Many of these fossils are of microscopic size. The layer of flint nodules that divides the 10 inch cutting course, is probably due to the metamorphosis and replacement of the bed of large shells of *Pentamerus oblongus*, that originally occurred at this horizon. At all events, the *Pentamerus* is sometimes found in the nodules, and the whole seam agrees, in its mode of occurrence, with the layers of the shell that are frequently met with in this series.

The most prominent fossil of the Springfield limestone has already been named, viz., the *Pentamerus oblongus*. It is found at a lower horizon here than to the southward. In Highland county, it is seldom found in the building stone series, its great multiplication being confined to the overlying beds, but in Clarke county and the regions immediately adjoining, it is almost equally distributed through both series. It is found in the lowest layers of the Springfield stone, but has not yet been noted in the division underneath. It attains its largest size at this horizon, some of the casts having a length of six inches. It never makes up the substance of the rock at this point, as it does elsewhere, but a great development of the form occurs in a thin seam, and then a foot or two of rock are added to the series, in which this fossil is not found. Perfect casts are of rarer occurrence here than in the beds above, but nowhere is the shell shown to better advantage than in the slabs to be obtained from all of the quarries which are covered and crowded with the full-grown valves. The best locality yet noted for these slabs is Col. Sinz's quarry, below the town. Other bivalve shells of the brachiopod division are found in the Springfield stone. Among them may be named the two very well known and widely distributed forms, *Orthis biforata* and *Atrypa reticularis* There may be added to these, *Orthis flabellum*, *Strophomena rhomboidalis*, and one or two additional species of *Pentamerus*. Chambered shells of the genus *Orthoceras* are quite frequently met with. The Niagara trilobite, *Calymene Blumenbachii*, (*Calymene Niagarensis*, Hall ?) abounds in many localities. These are the principal representatives of the life of the seas in which the Springfield stone was formed. There is an almost equal paucity of individuals and of species preserved in the rock, and, indeed, it is this fact which gives the series its value in large part, the occurrence of distinct and well preserved fossils, especially when they are of large size, almost always being unfavorable to the character of the rock for all architectural purposes.

4. The fourth division of the Niagara formation in the county is at once the thickest in its vertical section, the most widely distributed in area, and by far the most important in its products. It has been styled in the tabular view of the rocks of the county, the Cedarville limestone, and is recognized as the true geological equivalent of the Leclaire, Racine, Milwaukee and Bridgeport beds of the north-west, and of the Guelph formation of Canada. The name by which it is here designated, is taken from Cedarville, Greene county, where in numerous quarries this member of the group is disclosed with all its most characteristic fossils, and without the presence of any of the lower members.

A much greater thickness is found at the section under review, viz., at Holcomb's quarries, than at any other point in the county. There are 42 feet of the Cedarville stone quarried here, while one-half of this amount is a full average in the other quarries of the county. We find two subdivisions of this group, the lower and heavier being a massive rock, semi-crystalline in texture, retaining but few lines of bedding, and crowded often through all its substance with the casts of *Pentamerus*. Above this portion, certain thin, uneven-bedded limestones, sandy and porous in texture, but charged with a great variety of very interesting but poorly preserved fossils are found. Both of these sub-divisions are united popularly under a common designation, viz., "cap-rock." There seem to have been original differences in the rates of growth of the rock at different points—as the 40 feet section does not contain all that the 20 foot section has, and 20 feet in addition, but each is made up of the same elements, both of which are thickened in the first-named section, so as to make the aggregate greater. Within the limits of the city of Springfield, the cap-rock does not exceed 25 feet in thickness—the ordinary sections giving 20 feet.

The area occupied by the cap-rock or Cedarville beds, is almost co-extensive with the area occupied by the Niagara series in the county, as there are very few localities, and these of but small extent, where the cap-rock has been wholly removed by denudation, while the lower beds have been left.

The fossils of this division are far more abundant and far more interesting than are found in any of the divisions previously noticed. The occurrence of Pentamerus oblongus in this group, as well as in the underlying one, has already been alluded to. It is from this portion of the rock that the perfect casts are always obtained. The genera *Orthis*, *Strophomena*, *Atrypa*, *Rhynchonella*, *Eatonia*, are all represented here—some of them by several species. The number of chambered shells is also increased in genera, species and individuals. Among these forms

are several species of *Orthoceras*, one of which is *Orthoceras abnorme*, Hall, and others that are new or not identified. Some of them attain a large size, the living chambers being 5 or 6 inches in diameter, and the entire length of such shells being at least as many feet. Curved shells of the same great division, belonging to the *Cyrtoceras* or *Trochoceras* group are also found here. There is a considerable number of univalves, some of them of large size. The genera *Pleurotomaria* and *Platyostoma* are well represented. A large *Bellerophon*, of an undescribed species, occurs here also. The most interesting of all the divisions of animal life represented here, are, however, the crinoids and the allied group of cystideans. Prominent among them is the widely distributed Niagara crinoid, *Caryocrinus ornatus*. The internal casts of this species abound through all the series. The genus *Saccocrinus* is represented by several species. *Saccocrinus Chrisyti* is found everywhere, and at least three or four additional species of the same genus that are probably undescribed. The genus *Eucalyptocrinus* is also well represented. Among the recognized species, is the unusual form *Eucalyptocrinus cornutus*, Hall. Among the cystideans found here, may be named the genera *Holocystites* and *Gomphocystites*. Although these fossils are all internal casts, some of them still possess rare beauty, the plates having been replaced by crystalline carbonate of lime, and thus converted into lustrous faces that reflect light like mirrors. Some of them occur with stems attached, and occasionally the roots are also shown. Portions of the rock are often wholly composed of broken stems, plates and arms.

Trilobites of three or more genera, are met with in the Cedarville imestone. *Dalmania*, *Isotelus*, and *Encrinurus* are found, and occasionally casts of great perfection occur.

Corals also exist in considerable variety, but not generally in good preservation. The genera *Syringopora*, *Halysites*, *Favosites* and *Columnaria* are especially noteworthy. The first named of these forms often decomposes, and leaves the rock perforated with vacant spaces wherever its stems extended. The chain corals are very abundant and are often found in masses of considerable size.

In the description of the composition and contents of this stratum, a band of silicious limestone that ranges quite extensively through the series, must not be omitted. It occurs in the Springfield quarries, having a thickness of five feet at Petticrew's limekilns. It never has a great horizontal extent but often disappears within the limits of a single quarry. This silicious belt with its lenticular masses, illustrates very well one of the results recently obtained by deep sea dredgings, that beds

of limestone and flint may be contemporaneously deposited in closely contiguous areas. This belt furnishes very excellent and durable material for road making, but has no other useful application.

The Cedarville division of the Niagara group is seldom used as a building stone. It is not defective in point of durability, but occurring, as it does, in either a massive or very thin bedded form, instead of in even and convenient courses, it would be worked at a considerable disadvantage, as compared with the underlying series. To render the building stone accessible, however, the cap-rock must all be moved, and this in turn would add immensely to the expense of the building stone, were it not true that this division is itself possessed of such economical value that it would be quarried in great quantity though no fine quarries of building stone lay beneath it.

The Cedarville rock furnishes lime of a very superior quality, and has been turned to account for this purpose for a long time, and in very large quantity. Springfield lime, indeed, is the standard of excellence for all southwestern Ohio. As has been already intimated, it is the cap-rock only that is burned for lime in all of this district. The thickness of this series will be remembered as varying from 10 to 20 feet in the city quarries, and from 25 to 40 feet in the quarries below the town. The cap-rock is not perfectly homogeneous in character. Two principal sub-divisions have been already named in it, as shown in the mode of bedding, and by fossil contents in part. All of it, however, is magnesian limestone with the exception of the silicious element already noted, and the differences of the various belts in chemical constitution are confined within a very narrow range, the lime or the magnesia being increased or decreased a few hundredths, or the proportions of foreign substances, as silica and alumina, being slightly varied. The best form of the rock is very near to a typical dolomite, or double carbonate of lime or magnesia. Probably physical differences in the series interfere quite as much with its value for lime as these slight variations in chemical constitution.

The uppermost portion, it will be remembered, has a sandy and porous texture, though it is quite as free from silica as the lower beds. The lime produced from it is of equal strength and whiteness with that obtained from the more solid portion of the rock, but it is burned with a somewhat less degree of heat than the latter, and is therefore often overburned, as is shown by its becoming "sticky" in the kiln. The more solid stone of the middle and lower courses is consequently valued higher for burning than the uppermost beds.

The chemical composition of the stone is indicated in the following analyses, made by Dr. Wormley for the Survey. Care was taken in every

instance to obtain fair samples of the stone belonging to different quarries, but from some of the results, it must be judged that the samples do not fairly represent the quarries, especially in the 6th and 7th analysis.

	Silicious matter.	Alumina and sesquioxide of iron.	Carbonate of lime.	Carbonate of magnesia.	Silicates of lime and magnesia.	Total.
1. Frey's quarries, middle bed......	0.10	0.20	54.70	44.93	....	99.93
2. " upper bed........	1.50	1.00	54.70	42.37	....	99.57
3. Petticrew's quarries, middle bed..	1.30	1.80	55.40	41.48	....	99.98
4. " upper bed..	1.40	2.70	53.90	41.90	....	99.90
5. Holcomb's quarries....................	0.10	1.70	55.10	43.05	....	99.95
6. Moore's quarries......................	.4	80	46.40	47.53	....	98.83
7. Thompson's quarries..................	3.90	0.70	50.90	39.77	7.70	99.63

Probably every quarry has limestone as good as the best, and as bad as the worst, indicated in these tables. Aside from the differences already noted between the beds of sandy texture and the massive beds beneath them, there are no constant differences between the many quarries worked for lime burning. Every close observer will note portions of the series that he uses which are superior or inferior to other portions, but as all make marketable lime, all are burned together. The varying reputations of the limes from different kilns depends upon the varying degrees of care and skill exercised in burning the lime, rather than upon native differences in the stone that is used. There is, in fact, a remarkable degree of uniformity in chemical composition in the belts of rock that supply south-western Ohio with lime. Bierley's quarries in Darke county, Dugan's, near Sidney, Wilson's, north of Dayton, the Springfield quarries, those of Yellow Springs, of Cedarville, of Leesburg, Lexington and Greenfield, of Hillsboro and Locust Grove, all produce an excellent quality of lime. Many of the distinctions that are made in regard to them, as that one is a "hot" lime, fit only for paper making or gas purifying, or that another has a much greater degree of "strength" than the rest, will not, probably, stand the test of careful experiment. There are no "hot" limes in the series, and all of them have about the same degree of "strength." They vary slightly as to the readiness with which they can be slaked, and also somewhat in whiteness, so that for finishing purposes a well grounded preference may be exercised.

The modes of burning have been greatly modified within the last ten years, and are now rapidly approximating to uniformity. A dozen years

ago, the lime was all burned in kilns, holding from 500 to 1500 bushels of lime. This whole quantity was burned by a single fire, without any change in the contents of the kiln. As a consequence, some portions were overburned and others underdone, and more was got ready for use than the market required at once.

Patent draw-kilns have almost entirely displaced these older styled kilns, as was sure to be the case from the time when the former were first introduced. For the advantages that they furnish are so manifest and so important, the reduction of expense in the operation is so considerable, that in the burning of lime as a business, they rule out their old competitors peremptorily. The advantages are—

1st. They yield a *regular* product. A given number of bushels, from 200 to 300, can be depended on, every 24 hours. This product can be increased or decreased also to some extent, according to the demands of the trade.

2d. They furnish a *uniform* product. All of the lime that they turn out, if they are managed with skill, is of one quality as far as the burning is concerned, neither over-burned nor under-burned.

3d. They allow a greater division and economy of labor, and thus render a higher degree of skill attainable in those processes for which training is required.

4th. They effect a very considerable reduction of time in the process of burning. The limestone is in the kiln but little more than 24 hours, while in the former method, between two and three days were required.

5th. They effect a notable reduction of expense in the matter of fuel. The best results of the old kilns gave 50 bushels of lime to one cord of wood. In the patent kilns, 75 bushels are frequently burned with one cord. The average of the old kilns gives doubtless less than 40 bushels to one cord. The average in all well managed patent kilns, is over 60 bushels to the cord. As the market rates of wood at the kilns exceed $3.00 per cord, it will at once be seen that competition between the two processes cannot be permanently maintained. Two varieties of patent draw kilns are now in use in Springfield—viz: Page's patent, and the "Monitor." They yield equally satisfactory results.

Wood is the only fuel used in burning Springfield lime. Various experiments have been made in the substitution of stone coal, but none of them have thus far yielded satisfactory results. At Wilson's kilns, and also at Brown's, just west of the county line, cannel coal is at present used in part, in burning every kiln, but it is not claimed to effect any saving of expense, unless it be in the small item of handling the fuel. In these cases, the process is always finished by wood fires. Exper-

iments in the use of coal have been carefully made at Holcomb's, and at Frey's kilns. The same difficulty is reported from both—a lime being furnished that would not slake perfectly, but small grains of which would remain in the mortar, and afterward break out from the wall into which it was laid. Mr. J. S. Page, the inventor of one of the patent lime kilns largely in use, made experiments in a small way to determine the cause of this unequal slaking, and was led to believe that the presence of sulphur in the coal, produced the result. If this were true, the use of certain coal veins that have been found to be almost free from sulphur, would obviate the difficulty. There is good reason to doubt, however, whether the trouble is really caused in this way.

The character of the Springfield lime has already been incidentally alluded to, but it deserves a somewhat more extended notice. It is the standard of excellence as a finishing lime in the Cincinnati market and for all southwestern Ohio. It is carried in considerable quantity into Kentucky, and finds its way even to New Orleans. The qualities of the lime that especially recommend it are its mildness, its whiteness and its strength.

Its mildness results from its chemical constitution. All the varieties of magnesian limestones, make what are called "lean" or "cool" limes. They slake with little heat and do not "set" or harden rapidly. Although they require more time for slaking than the "fat" limes, they can be used more promptly after the operation is finished, for unlike the true carbonates of lime, they have no tendency to contract in drying so as to mar the wall with minute fractures or "chip-cracks." Thus, in all ways, they ensure economical working.

The quality already described, does not militate against another of even more importance in mortar than this—viz: the strength and permanence of the cement which it furnishes. There is no more durable lime cement used in Ohio than Springfield affords. A wall built of it, in a few years, acquires such hardness that a nail can be driven more easily into a well-burned brick than into the mortar which holds it to its place.

The presence of the magnesia seems also to add hydraulic energy to the mortar to some degree, making it able to withstand the dissolving action of water.

It seems almost necessary, from facts like these, that the statements in regard to limes in our most authoritative works, should be revised. The purport of these statements, without exception, is, that the higher the percentage of carbonate of lime in mortar, the higher is the value of the mortar.

Ohio has large supplies of limestone containing from 84 to 96 per cent. of carbonate of lime, the 4 to 16 per cent. of the remainder being composed largely of carbonate of magnesia. In southwestern Ohio these limestones are even more accessible than the magnesian stones of the Cedarville horizon. In fact, they have to be crossed before the latter can be reached. They had the advantage also of priority of use, most of the lime burned 25 years since, being derived from these kinds of rock. They have been, however, everywhere displaced, so that there is scarcely a kiln in operation among the purer limestones in this whole section of the state. It is true that the magnesian limestone, can be burned with less expense of fuel than the other kinds, but the change was not made on this account, but solely on account of the intrinsic excellence of the lime produced. The change was made by practical men, who were wholly intent upon securing the best results most economically. The advantages of a "cool" lime, are counted so great that lime of the opposite character can scarcely be given away to the builders of Cincinnati.

It certainly seems desirable that a careful, scientific investigation should be instituted with reference to the very different qualities of lime that are now in the market. Whenever such an examination and comparison shall be extended to all the points named in the preceding discussion, it will be found that the lean limes, of which the Cedarville limestone is the type, deserve a very different place in the classification from that previously assigned to them—in fact, that the last of the old estimate shall become the first of the new.

The quantity of lime annually produced in Springfield and its immediate vicinity, is very considerable. It is not less than 500,000 bushels, and during some years it has largely exceeded this amount. The parties already named as dealers in Springfield stone, are the lime burners also—the two branches of business being necessarily connected, as will be understood from the relations that the building rock and limestone bear to each other.

The business can be seen to the best advantage at the extensive quarries and kilns of W. H. Moore and A. & W. Holcomb, three miles below Springfield. These parties have the best hold upon the outside trade by reason of their railroad facilities, the kilns of Moore being located directly upon the line of the Sandusky road, and Holcomb's on the Atlantic and Great Western road. The location and arrangements of Holcomb's kilns leave little to be desired in these particulars. Every part of the business is systematized and carried on at a minimum of expense, and the product of the kilns is not surpassed in uniformity.

The following statements, furnished by Albert Holcomb, Esq., show in

detail the cost of producing a bushel of lime under the most favorable circumstances. The estimate is made from the business of the firm for the year 1871. It is calculated in part from the following items:

Total production of lime for the year	104,594 bushels.
Average cost of wood per cord	$3.48
Average production of lime per cord of wood	56 bushels.

The wood used previous to July 1st, being inferior, produced only 47 bushels per cord of wood and two-fifths of the year's product. The wood used after July 1st, was of good quality, and produced 63 bushels per cord and three-fifths of the year's product.

Labor, including stripping and cleaning quarry, drilling, breaking rock, burning lime, and loading into cars, per bushel	$0.0728
Wood	.0623
Powder and fuse	.0040
Incidental expense	.0063
Total cost per bushel	$0.1454

The rent of the quarry and foreman's wages are not included in the above estimate.

For the first six months of the year a still more detailed statement is furnished, the cost of the labor being distributed among the several items involved:

Stripping and cleaning quarry and handling wood	$0.0161
Drilling	0.0125
Breaking rock	0.0153
Burning and loading	0.0309
Wood	0.0692
Powder and fuse	0.0044
Incidental expense	0.0064
Total cost per bushel	$0.1548

It has already been stated that wood is used exclusively in the lime-burning of this region. The average amount of lime burned by one cord of wood has also been given. Taking all the kilns and the various qualities of wood used into the account, it is not probable that the general average rises as high as 50 bushels of lime to one cord of wood. But assuming this rate for the present, we find that the burning of lime in and around Springfield requires annually 10,000 cords of wood. An average of such woodland as is now brought into the market, will yield 50 cords to the acre. The consumption of the Springfield kilns then requires the annual clearing of 200 acres of woodland in the vicinity of Springfield. This is a severe demand, and cannot be permanently met

without materially increasing the cost of the lime. It is greatly to be hoped that coal can be successfully applied to this work, as it has been to so many others for which wood was once counted indispensable.

It is worthy of mention in this connection, that the farmers of the vicinity have almost entirely neglected the great supply of fertilizers that the ashes, charcoal and lime-waste of the kilns furnish. Not one bushel in ten thousand has ever reached its only proper destination, viz: the land which has been despoiled of its forests for the carrying on of this process, but ashes and lime have been turned to unseemly and unprofitable uses—made into road beds around the quarries, drawn out to fill waste ground, or even carted to the banks of the streams to be swept down by the floods. Quite recently the ashes have been sifted and turned to economical account in soap-making, but still great quantities of the remaining products are accessible, to repay many fold the expense and trouble of applying them to the half exhausted lands that surround the kilns on every side. The wood wagon from the farm should be transformed into an ash wagon from the kiln.

Nor should the ashes be neglected when the soap-boiler has extracted from them the most of their potash. They still contain in large quantities the most important mineral food of plants.

As the excuse for such neglect is sometimes made that the application of ashes and lime stimulate the growth of white clover at the expense of blue grass and other more desirable products, it may be added that these mineral fertilizers should be applied to crops with the same degree of care and observation that good farmers use in the application of ordinary manures. For instance, let the ashes and lime be applied as a top-dressing to fall sown wheat, which is to be seeded with clover—or to clover fields which are to be plowed under green, and the results cannot fail to be most satisfactory and beneficial. Attention is earnestly invited to this subject, for though but a small portion of the county can be directly benefited by wise use of the substances named, a breaking up of the general indifference in regard to questions of such vital importance in the agriculture of the county, ought to be looked upon with the greatest interest.

The leading facts in the Geology of Clarke county have now been passed in brief review. It is seen that in its limestone and building rock, it has a fair share of mineral wealth, while its soil, its surface-relief and its water-supply, place it among the best counties of the state. No more characteristic view of the great excellence of south-western Ohio can be obtained from any point than from the ridges and hills around Springfield. From its earliest history, the county has been, as it

now is, in the hands of a thrifty, intelligent and enterprising population. Its main town, Springfield, is a model of business energy and sagacity. It has always displayed a wise foresight in the encouragement and establishment of manufacturing enterprises, and reaps the results in its prosperity to-day.

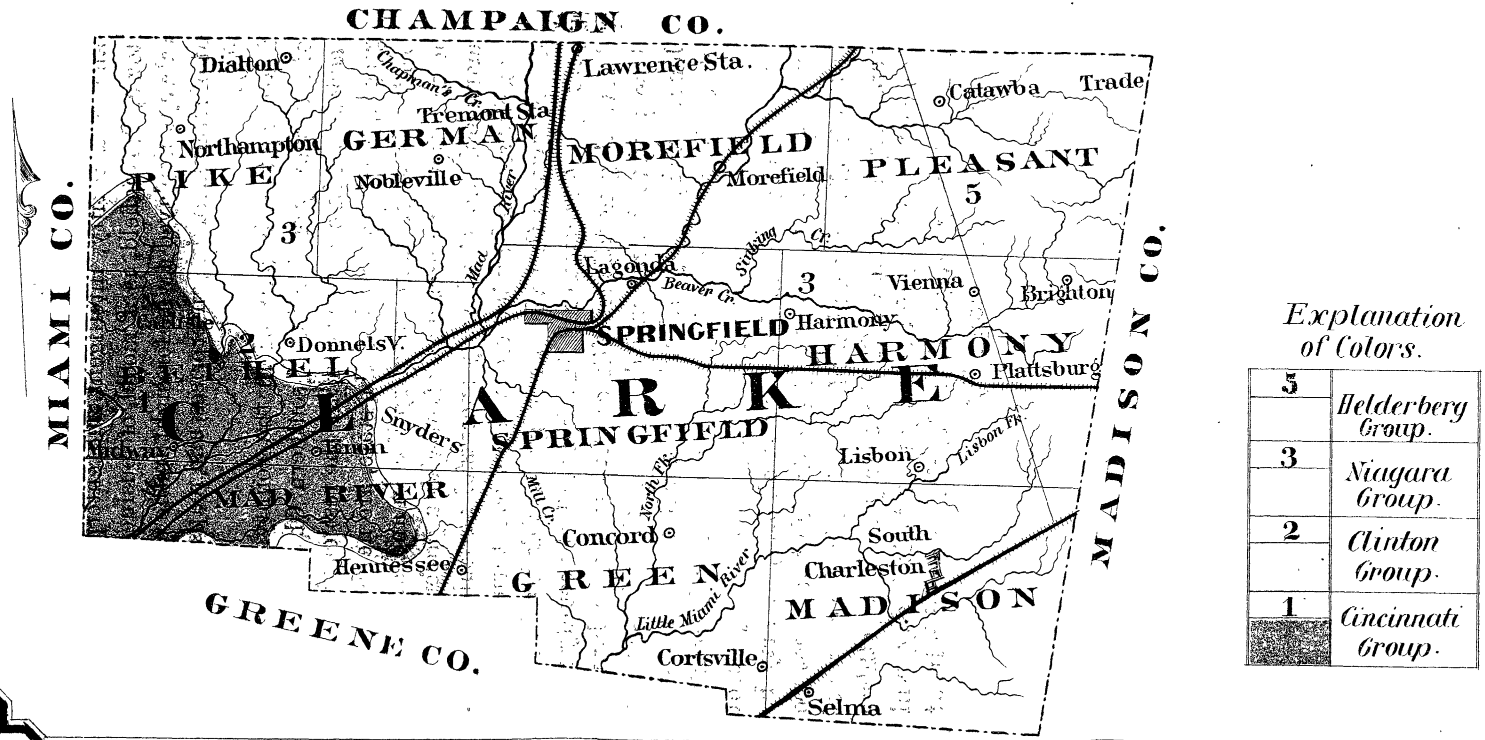
The system of farming that is pursued in the county is in no wise inferior to that of any county or district of southern Ohio. But truth requires it to be added that in common with all the rest of this portion of the state—if geographical lines within the state, are needed at all—the system of farming is essentially one of spoliation and exhaustion. There is a wanton violation—connected too often with a profound ignorance—of the fundamental law of all truly successful agriculture, viz., that the mineral food abstracted by the crops, must be returned in fertilizers to the soil. No system that violates or ignores this law has any possibility of perpetuity. A generous soil like that of Clarke county may fill the homes of several generations with comfort and even luxury, though no regard be paid to the rational demands of the soil—but an end will come at length, and poverty and exhaustion will take possession of the fields which ought instead to teem with constantly increasing agricultural wealth. Such a result will certainly follow the present system of agriculture. Indeed, it is following it already, as may be clearly read in failing crops and shrinking harvests. But it is not too much to hope that the intelligence and thrift that have in the course of two or three generations, transformed Clarke county from a pathless wilderness into the rich and beautiful country that it is to-day, will be brought to bear upon those great questions of agriculture which lie at the very foundation of our material prosperity.

Geological Survey of Ohio.

GEOLOGICAL MAP OF CLARKE COUNTY

BY

Edward Orton.



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REPORTS ON THE GEOLOGY

OF

ASHTABULA, TRUMBULL, LAKE AND GEAUGA COUNTIES.

BY M. C. READ.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—I have the honor to submit herewith reports on the geology of Ashtabula, Trumbull, Lake and Geauga counties.

Your obedient servant,

M. C. READ,

Local Assistant.

CHAPTER XVII.

GEOLOGY OF ASHTABULA COUNTY.

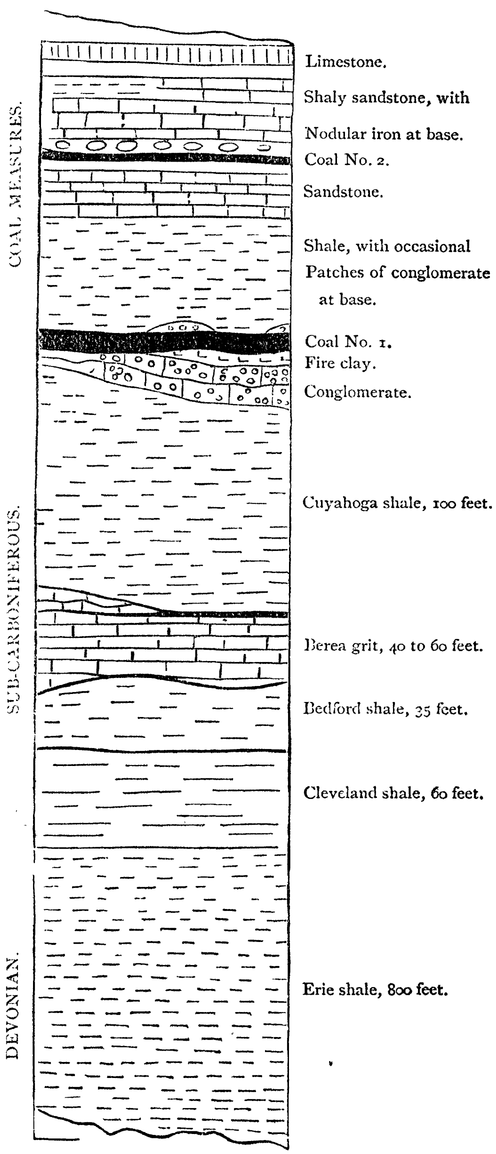
The geology of Ashtabula county is so closely connected with that of Trumbull, that much of the description given of the former county will serve equally well to illustrate the latter. Taken together, these two counties include a connected section of rocks, of which the oldest are exposed on the Lake shore in Ashtabula, the most recent in the southern part of Trumbull. The section represented in the subjoined woodcut embraces all the strata which come to the surface in the two counties.

Of these rocks, those below the Conglomerate are alone found in place in Ashtabula county. In the east part of Williamsfield, a high ridge is capped with the Conglomerate, which has supplied a large part of the stone used in building in that part of the county. It is in blocks and masses of large size, but evidently much below its geological horizon, having resisted the pulverizing and denuding agencies which have removed the strata below it. The Cuyahoga shales underlying the Conglomerate, are the surface rocks in the central part of Wayne and the western parts of Hartsgrove and Windsor, but are covered by soil and Drift. In the latter two townships their position is indicated by a long stretch of level, wet, tenaceous clay soil, productive and well adapted to grazing when fully reclaimed, but cultivated with difficulty unless artificially drained. In Wayne these shales are more silicious, and the soil is somewhat more gravelly.

BEREA GRIT.

The Berea grit is a well defined deposit of moderately coarse sandstone from forty to sixty feet thick—in some places massive, in others in thin layers—generally gray from minute specks of iron, and sometimes spotted with iron stains. The important quarries at Berea have given this

Section of the Rocks of Ashtabula and Trumbull Counties.



formation a name by which it is frequently designated, although it is also known as the "Amherst stone," the "Independence stone," and in New York as the "Ohio stone," and sometimes as the "Cleveland stone." It is the most important quarry rock in Ohio, and in many places supplies material for excellent grindstones. It enters Ashtabula county from the west, in Trumbull township, and near Footville has been quarried to a limited extent for whetstones, for which it is there very well adapted. Only a small part of the ledge has been exposed, and full explorations there would probably disclose good material for grindstones and for building purposes. Its outcrop extends southward through the center of Hartsgrove, east of the center of Windsor, and west of the center of Mesopotamia, striking the north-west corner of Farmington. When not exposed, its position is marked by a ridge rising towards the west, covered with fragments of sandstone, and along the whole length of this ridge it has a comparatively thin covering of soil. The best exposures are at Windsor Mills, where the stream has cut a channel thirty to forty feet deep through the rock, and where it has been quarried for many years for local use. The demand for stone has been so limited that no one has been induced to open up the quarries with any system, and the stone has been obtained at great disadvantage and without any thorough ex-

ploration of the ledge. The high ridge east of the stream, over which all the stone for the central part of the county has to be taken, is composed of the same rock exposed in the gorge, and whenever the demand shall warrant systematic quarrying, openings may be made at the eastern base of this hill, and the stone be taken out to the bottom on that side. As none of the rocks below this afford any really good building stone in the county, a demand for that from this ledge must soon arrive, which will justify the construction of a railroad to it. When this is accomplished, the whole county will be supplied with stone from this source, and the extensive region along the lake shore, destitute of good building stone, will draw a large part of its supply from this locality.

At Mesopotamia, in Trumbull county, this rock has been quarried, where exposed by the streams, and layers of it were used many years ago for the manufacture of scythe stones. Some of it there is a good grindstone grit, and the whole ledge should be thoroughly explored, as it will probably yield good stone, both for building and for grindstones, in an unlimited quantity.

The same stone crops out in the eastern part of Colebrook, and near the northern and eastern parts of Wayne, being here hard and strong; at most of the exposures it is so colored with iron as to be damaged for building, but neither its strength nor durability is impaired by this cause.

A third bed of shaly sandstone, having all the lithological characteristics of the Berea grit, passes through Williamsfield, and may be observed in two ravines, one a half mile and the other a mile south of West Williamsfield. It is separated from the body of the Berea by fifteen or twenty feet of argillaceous shales, is apparently thin, and gives promise of no really first class stone. At other places, this formation will range from forty to sixty feet in thickness, and will furnish an inexhaustible supply of valuable stone for bridges and foundations, and probably an abundance of first class stone for other uses.

BEDFORD SHALE.

The Bedford shale, underlying the Berea, is in the western part of the county quite thin, not exceeding thirty-five feet thick, and is mostly composed of soft friable aluminous strata, the basis of a tenaceous clay soil, where the debris covers the surface. In the eastern part of the county they are thicker, harder and more silicious, and this changed character has modified the topography and soil of that part of the county, producing a more irregular, undulating surface and a more porous soil. These shales furnish, in places, considerable quantities of hard, firm stone in thin layers, but no really good quarry rock.

CLEVELAND SHALE.

This black, bituminous shale is exposed in the ravines in Trumbull township, exhibiting there a maximum thickness of sixty-five feet; the upper thirty feet being a typical black shale, the lower thirty-five feet gradually assimilating to the character of the Erie shale below. When the transition from the Cleveland shale to the Erie shale is sharply defined, as in the valleys of Chagrin river and the Cuyahoga, their differences produce a marked effect upon the topography and the character of the streams. In the latter, if rapid, a water fall usually occurs at the horizon of the black shale, which is also usually indicated by a bench in the sloping hills away from the streams, so that the strike of its outcrop can often be accurately determined, even when covered by drift and soil. When the transition is gradual, however, no perceptible effect is produced upon the topography, and the line of separation can be ascertained only where the rocks are fully exposed. The Cleveland shale is generally a highly bituminous rock, with a strong odor of petroleum, splitting neatly into thin layers, containing a small percentage of iron, weathering into a stiff, tenaceous yellow clay. In the eastern and southern parts of the county, this shale either thins out or is entirely covered and concealed by the drift and alluvium. As the dividing line can not be traced between this and the Bedford shale, the two are grouped together upon the map, the territory supposed to be covered by them being colored with the same tint. In the lower part of the Black shale in Trumbull township, where it is changing its character to that of the Erie shale, there are layers containing very beautiful specimens of *Discina Newberryi*, and a profusion of *Conularia*. These fossils are also found in the Cuyahoga shale at Vernon, Trumbull county.

ERIE SHALE.

By far the largest portion of the county, that shaded green on the map, is covered by the Erie shales; and they are from 800 to 1,000 feet thick, and extend far under the lake. While there are places where their southern limit is clearly defined, there are others where, for reasons already stated, their boundary can be fixed only approximately. The Erie formation is composed almost entirely of soft, blue, aluminous shale, often weathering red on exposure, and finally decomposing into a stiff, yellow clay. Hard layers, from one inch up to one foot in thickness, are interstratified through these softer shale, but these bands are full of vertical seams, and are rarely of sufficient solidity to offer much resistance to denuding agencies. The Erie shale gives a peculiar character to the

topography and soil of the county. South of the lake ridges, and within the limits of this formation, the surface is one broad, level plain of stiff clay, except as it has been eroded by water and modified by occasional, but rare, deposits of gravel from the drift. From the absence of any rocks offering special resistance to erosion, the surface has been left gently undulating, without benches or abrupt changes in the slopes of the hills. Where the streams are rapid, they form deep and narrow gorges, cutting down almost precipitously sometimes one hundred feet into the shale. The stiff clay soil derived from the decomposition of these shales, where not exhausted by injudicious tillage, is highly productive in favorable seasons. But the retentive soil resting upon impervious clay shale, having no fissures through which surplus water can escape, renders a little excess in the rain-fall extremely injurious. The same causes render protracted dry weather equally destructive to the growing crops. Fortunately, the surface of the county is generally sufficiently undulating to render thorough under-draining practicable. And, probably, there is no county in the state where a systematic resort to this improvement would result in greater benefits than here. The soil is rich in potash and other essential minerals. It will retain and hold the soluble parts of all fertilizers added to it, and, although especially adapted to grazing, when thoroughly under-drained it will become fitted for the growth of all ordinary agricultural products of this latitude, and its average annual value for grazing purposes will be nearly or quite doubled. Such soils, when properly prepared, and the surplus water drained off, are not excelled by any for the cultivation of apples, pears, quinces and grapes, the most important and profitable of our fruits.

As these shales contain a considerable amount of calcareous matter, it is probable that there is no deficiency of lime in the soil. If experience should show a want of this essential ingredient, the net work of railroads now building in the county will make the limestone of Sandusky easily accessible.

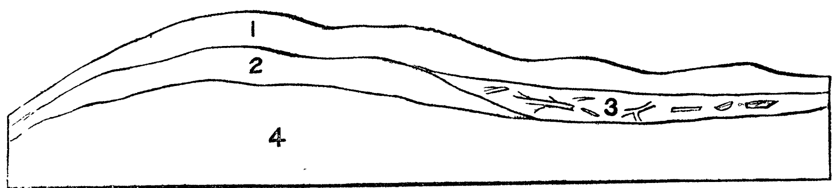
The deep gorges cut through the Erie shale, show in many places important deposits of lime, in the form of calcareous tufa, which has its origin in one or more of the hard bands of the shale, which is so calcareous as to become in places a true limestone. The rain-water charged with carbonic acid, dissolves the lime, and so deposits it in favorable places, some of the accumulations observed being sufficient to furnish a large amount of lime for agricultural and other purposes. Numerous specimens of a new species of *Leiorhynchus* have been obtained from the bed of Ashtabula creek, in blasting out the channel of the harbor, but most of the lower part of the shales exposed in the county contain few

fossils. On the head waters of streams emptying into Ashtabula and Conneaut creeks, however, where the upper layers of the shales are exposed, a great abundance of *Rhynchonella*, *Leiorhynchus*, *Spirifer*, &c., can be obtained.*

LAKE RIDGES AND TERRACES.

The old "lake ridges" and terraces, are well defined in the county, and railroad excavations have afforded unusual facilities for studying their character. The outer or southern ridge, where exposed by railroad cuts, is shown to be a ridge or wall of compact, unstratified clay, composed largely of the debris of the local rocks, but with many fragments of granite and other metamorphic rocks, not rounded by the action of the waves but in irregular forms, ground, polished and marked with striae and scratches on all sides.

The following sections of this ridge are especially instructive. The first is an exposure in south ridge by the A., Y. & P. R. R.



Section of South Ridge, Ashtabula, Ashtabula Co., O.

The summit of the ridge at this place is 202 feet above the Lake. No. 1 of the section, is composed of water-washed sand and loam, from four to six feet thick, the maximum thickness being south of the crest of the ridge, where the sand is stratified in billowy lines, evidently carried by the wind from the old beach on the opposite side. No. 2, is yellow clay, and No. 4, blue clay, the first varying in thickness from twelve feet to nothing, the latter, twenty feet to the railroad track. Both these deposits of clay are unstratified, filled with fragments of the local rocks,

*Kelloggsville, Ashtabula, Pierpont, Morgan, Rome and Jefferson, may be mentioned as localities from which interesting fossils have been obtained in the Erie shale. They consist of *Leiorhynchus mesacostalis*, *L. quadricosta*, *Spirifera disjuncta*, *S. alta*, &c., &c. With these and some others which are well known Chemung fossils of New York, are many new species, which will be found figured and described in the paleontological portion of the report. The Erie shales are the extension westward of the Chemung, and upper half of the Portage Groups of New York, here diminished in thickness, more argillaceous in composition, and so blended as to be inseparable.

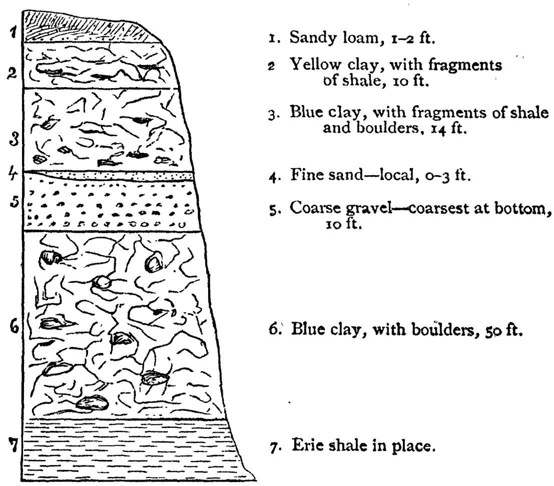
J. S. N.

apparently having derived the great mass of their materials from them, but containing many fragments of metamorphic rocks, marked with striae without water-worn pebbles or bowlders. No. 3, is an old swamp, containing fragments of coniferous wood, the earth deeply stained with iron, and in places with deposits of bog iron at the bottom, the whole now covered to the depth of about six feet with drifted sand. This swamp had its origin in the causes which raised the clay ridge into its position, and was evidently filled with swamp vegetation at the time the waters of the lake were resting upon the northern slope of this ridge, the winds gradually carrying the beach sand over the crest of the ridge into the swamp basin, and in time burying it beneath the constantly accumulating sandy deposit.

At the point where the Ashtabula and Jamestown railroad cuts through this ridge, a section is made down to within about twenty-five feet of the shales, the cut passing through the yellow, and about half way through the blue clays. On the banks of the Ashtabula creek, a few rods to the south, the shales are exposed, revealing to the observer all the materials of the ridge.

The following is the section at that point:

Section of Drift Clays, Ashtabula, O.

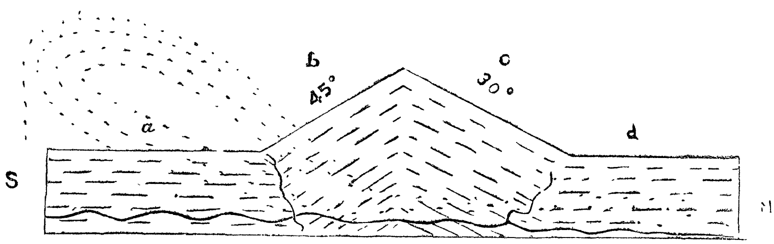


The yellow and blue clays are wholly unstratified, composed of the debris of the Erie shales, with numerous fragments of granitic rocks; the coarse gravel in the middle of the section is of similar fragments, with the clay washed out of it. The mass bears no resemblance to the shingle of a water-washed beach, the gravel not being polished and

rounded into pebbles, but apparently the result of a mass of mud pushed up into a position where drainage has carried off the softer and more liquid materials. The local bed of sand, 4, above, is stratified, indicating a temporary local space of open water apparently soon closed up, and the ice pushing the unstratified clay above it. This ridge, with its mass unstratified, and without rounded, water-worn pebbles, can not be the slow accumulations of a water-washed beach, nor can the materials have been deposited in any way which permitted them to fall through water which would sort and stratify them.

A section of the shale in the bed of the old lake, exposed by a shallow ditch near the depot of the L. S. R. R. at Ashtabula, is very suggestive, as to the nature and direction of the forces which scooped out the lake basin. A fracture of the shales is there disclosed, forming a sharp anticlinal ridge with the layers of the shale quite horizontal, at a distance of less than 10 feet north and south of the axis, as in section below.

Broken Strata of Erie Shale, Ashtabula, O.



On the north of the axis the shale dips to the north at an angle of about 45°, and on the opposite side, to the south, at an angle of about 30°.

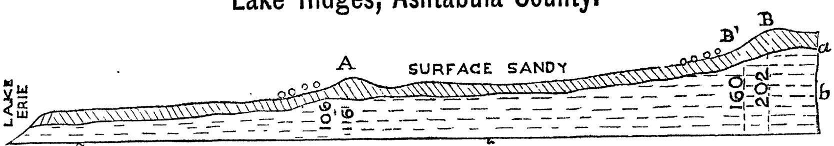
It is manifest that such a local break in the shale could be caused by neither an upheaval nor a subsidence of the strata. A vast mass of ice moving from the north and impinging on the exposed strata of the shale with sufficient power to cause a part of the strata to slide upon those below and to buckle upwards at some point where the sliding motion was arrested, is alone competent to produce the condition of things here seen. The movement of a glacier, like a sheet of ice, is the only known force likely to produce such a result.

Had the movement which caused this local axis continued far enough to crush the material marked *b*, *c* and *d*, pulverizing it to a clay, carrying part of it up into the part marked *a*, into a ridge, and leaving it in the position indicated by the dotted surface, we should have here precisely the section disclosed in Lake county at a point where Grand river cuts through the south ridge, the strata there being cut away fifteen to

twenty feet lower just north of the ridge, than they are directly under it. The south ridge throughout Ashtabula county appears to mark the line where the outer margin of the ice carried up the debris of the shales scooped out of the lake basin on to the strata which it had not force enough to remove. This force left the pulverized shales in the form of a heavy deposit of blue clay, at the bottom of the excavated basin, on the ridge left at the margin, and on all the lower regions beyond, where the force broke through or over this ridge. The yellow clay and the sand ridges to the north, mark subsequent chapters in this recent geological history.

The ridges north of the south ridge are composed of sand and gravel, irregularly stratified, the intervening surface covered in places with fine sand, in others, with clay or mingled clay and sand. While there are several irregular broken ridges in places, there is only one interior ridge which is continuous through the county, the two having the relations shown in the following section, with the present surface of the lake:

Lake Ridges, Ashtabula County.



a. Drift clay. *b.* Erie shale.

A and B represent the two continuous lake ridges, averaging in the county about one mile apart. The spaces between them and between the north ridge and the lake, presenting to the eye the appearance of level terraces, but sloping gradually toward the lake. The records of icebergs in the old lake, at comparatively recent epochs, are left in the granite bowlders scattered along the north slope of both of these ridges, most abundant on the slope of the northern ridge, generally not upon the surface, but so slightly buried that they are uncovered by the plow in cultivation, and in many places so thickly scattered in the soil that it is necessary to remove them to prepare the land for tillage. The continuous covering of irregularly stratified sand and gravel from B' to A, indicates a very slow and gradual subsidence of the water, bringing all parts of the intervening space successively under the action of the shore waves, so that the inner ridge has gradually moved from B' to A, in places the wind carrying the drifting sand up over the ridge and leaving irregular sand ridges and dunes on the outer margin of the receding ridge. The sand ridge at A, marks a somewhat sudden subsidence of the lake level for ten to twelve feet, while the gentle slope between it and the present

shore, marks a long continued and slow subsidence of 106 feet; the irregular ridges and dunes of sand which are to be seen at various places on this slope, also being formed by the wind carrying the light, fine sand over the ridge or beach which marked the receding shore.

In preparing the bed of the A., Y. & P. R. R. north of Ashtabula village, cuts have been made in two clay hills, which were evidently islands when the north ridge bounded the margin of the lake. These cuts afford interesting and peculiar exposures of the Drift clay. In one of them the blue clay is in blocks, with nearly parallel sides, embedded in the yellow clay; the portion next to the blue in layers, the structure closely resembling blue iron ore, with an oxydized shell on the outside of it, and suggesting at once the idea that the blue clay was here oxydized in place, and was thus changing to a yellow clay. The whole of the clay is well fissured in all directions, the fissures being from one to six inches wide, filled with yellow laminated clay, the line of lamination parallel with the sides of the cracks. Most of these cracks were so connected as to divide the clay into blocks, but all the cracks are connected with the surface, and are all filled with yellow clay of the same character as the upper mass.

The other clay hill gives a similar section, viz:

1.	Sand, stratified by wind	4–10 feet.
2.	Yellow clay, upper surface undulating	6– 8 "
3.	Blue clay	15 "
4.	Erie shale, exposed	6 "

The clay is cracked and the seams are filled with yellow clay, as in the other hill. These clay hills are nearly on a level with the south ridge, and furnish additional evidence of the sudden subsidence of the lake level, the rapid dessication of the clay causing it to crack and become filled with seams and fissures as observed.

CHAPTER XVIII.

GEOLOGY OF TRUMBULL COUNTY.

The county of Trumbull is of special interest to the geologist, from the fact that it contains within its limits one of the two productive oil districts of the State, and the most northern extension of good, workable deposits of coal.

It is composed of twenty-five townships, in a square form, with a soil uniformly good and productive. To the casual observer there will appear to be nothing striking or peculiar in its topography; but the section through the county from Parkman, in Portage county, eastward through the centers of Farmington, Bristol, Mecca, Johnston and Vernon, to the Pennsylvania line, given on a succeeding page, shows that it forms a broad trough or basin, scooped out of the Carboniferous and Sub-carboniferous rocks, the interior marked by long, gently sloping ridges, separated by the water-courses. That the Coal-measures formerly extended quite to the northern limit of the county, and, perhaps, far beyond it, is rendered probable by the following facts. On the east and west of the county the coal rocks now extend much farther north, the formations on each side being level, undisturbed, and on the same horizon. Fragments of the block coal, of considerable size, are often found in the sand ridges near the northern part of the county, and occasionally beyond its northern limit, while these ridges are composed, apparently, largely of the *debris* of the Coal-measure sandstones. Other facts show plainly that the direction of the drift forces which scooped out the valley was toward the south, and there is no known transporting agency which could carry these fragments of coal north of their place of origin. They point, therefore, to a condition of the surface before the drift period, when the Coal-measures of western Pennsylvania continued in one unbroken sheet across this county, to the long north and south ridge in Portage and Geauga, now capped with the coal rocks. In the section

before referred to, the position the Coal-measures are supposed to have occupied, is indicated by the dotted line connecting No. 1 at the left with the corresponding number at the right of the section, and which represents the geological horizon of the block coal. It would be useless to attempt to compute the amount of coal thus mined and removed by the old glaciers, which have left their marks in many parts of the county, but the *debris* of this coal and its including rocks, ground to a dust, is, in part, mingled with the soil of the county, and in part has been carried southward and contributed to the vast deposits of alluvium of the Mississippi valley. These fragments of coal are not, as is often supposed by the farmers who find them, indications of coal now to be sought in the neighborhood, but are fragments from coal beds formerly occupying a much higher level, and which the forces that prepared the soil beds for the agriculturist have removed ages ago. The stiff, tenacious clays of the drift cover a large part of the county, producing a soil especially adapted to grazing, but the fertility of which is much impaired by any slight excess or deficiency in the amount of rain. The average productions of all such soils would be nearly doubled by systematic under-draining, which would largely prevent injury to the crops both by rains or drought, and in all seasons increasing very considerably the depth of the soil available for the support of vegetation. The farmers of some parts of the county have found by experience that wet seasons are productive of much greater injury to their crops than was the case some years ago. This is mainly due to the fact that the roots of the old forest trees, piercing the ground to a great depth, and interlocking in a complete net-work, by their slow decay, left numberless channels which, for a long time, afforded conduits for carrying off surplus water, and constituted an efficient system of under-drainage. Cultivation and the settling of the soil, has completely filled up and obliterated these drains, and resort should be had to draining tile to supply their place and restore the original productiveness of the soil.

These drift clays, in many places, especially near Pymatuning and Mosquito creek, are covered by a fine sandy soil, the *debris* of the Berea grit, the Conglomerate, and the Coal-measure sandstones. These sand ridges are results of the geological structure of the county, and are important aids in tracing the outline of the different formations. They invariably point to the outcrop of one of the sandrocks of the county, ordinarily at a little higher level, and parallel with the ridges.

While nearly the whole breadth of the county was formerly a channel by which the waters from the north passed into the Mississippi valley, there were also smaller channels cut down much below the present level

of the valleys. The present water-courses, where explored, are found to be running sometimes one hundred feet above their ancient beds. A deposit of clay fills a wide channel, passing through Farmington and Southington into the Mahoning valley. At the center of Southington wells have been sunk to the depth of one hundred feet without reaching the bottom of this clay, while on the south line of the county, near the center road, and also near the western line of Champion, the rocks are to be seen in position near the surface. This old channel continued probably near the south-east corner of Southington into the valley of the Mahoning; and, although this stream has in places a rock bottom, its ancient bed will be yet found somewhere in the valley at a depth of one hundred feet or more below the present water level.

THE COAL-MEASURES.

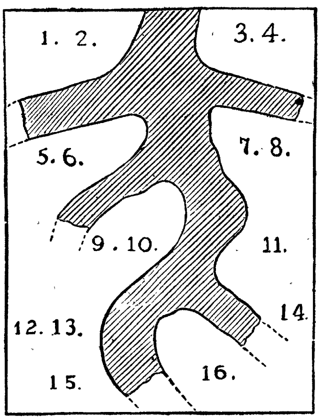
In the southern and south-eastern parts of the county, the rocks associated with the lower or "block coal" underlie the surface, except in the immediate valley of the Mahoning and its tributaries. The whole of Hubbard and Brookfield townships, the greater portion of Hartford, Vienna and Liberty, a part of Lordstown, Newton and Weathersfield, and some small patches in Vernon and Fowler, are covered with the coal rocks, the limestone above coal No. 3 being the highest member of the Coal-measure deposits exposed in the county. The brown shading upon the map, opposite page 483, exhibits with approximate accuracy the northern limit of the coal. In places, the outcrop of all the rocks is covered by drift, and reliance is placed upon the topography to connect the nearest adjacent outcrops. Explorations may make some corrections necessary, but, in all essential points, the map may be regarded as substantially accurate.

Over this area, the coal is by no means continuous, or uniform in thickness and quality when found. It lies in patches and basins of irregular forms, and sometimes of small extent, indicating a very irregular surface of the land when it was deposited; a surface covered with scattered swamps and marshes, sometimes running in a long connected chain, and sometimes quite isolated; precisely as we often see the peat marshes of the present day. A search for this coal is a search for those old swamps, since covered up and hidden by the materials which have been consolidated into shales and sandstones, these also being usually covered by a drift and soil.

When this covering is of uniform character, and no excavated ravines cut through the coal, the search must of necessity be difficult and expensive.

The geologist can ordinarily define with accuracy the limit of the territory in which the search may be successful, and can make a close approximation to the depth below the surface at which the coal will be found; but the search at that depth and within those limits can be made only by piercing the strata by boring, shafting or drifting, with the certainty that barren regions will often be thus penetrated between the margins of the old swamps, and that in other places swamps will be explored which were so shallow that they could not contain a thick deposit of carbonaceous matter, and in which the coal will be found too thin to work. Such also was the very irregular outline of these old swamps, that the rocks may be pierced in many places, in a valuable and productive territory, and no coal be struck in drilling.

The following plat of Crawford, Davis & Co.'s mine, of Hubbard township, mapped by the engineer of the company, after the coal was mined, exhibits the irregular outline which characterized many of these swamps, and the liability, after making what, in ordinary circumstances, would be deemed very thorough explorations, of abandoning territory as worthless, which, in fact, contained very valuable deposits.



The area over which the coal has been mined is about sixty acres, and is indicated by dark shading. The dotted lines show the probable boundary of the unmined coal, and the unshaded portion the parts of the territory where there is no coal. Explorations by boring made at all the points marked by numbers 1 to 16, which would be considered a very thorough exploration, would disclose no coal, yet from all the dark colored portion of the plat, coal of excellent quality and of the ordinary thickness has been mined at a large profit to the operators and the owner of the land.

The superior quality of this coal should prompt to a thorough exploration of all the territory in which it can probably be found, with the certainly that large profits will accrue from a successful search. In addition to these profits to the operator, he may well be accounted a public benefactor who shall discover and make available important deposits of iron-making coal.

If the explorer will remember that these coal basins were once precisely similar to the surface-marshes of the present time, it will aid him greatly in his search. He will understand why, when a seam of any

thickness below the maximum is struck, he ought to expect it to become thicker in one direction, that is, toward the center of the old swamp, and thinner in the opposite direction. And why, where two or more basins partially connected are disclosed, he ought to expect to find others connected with them, forming a chain of swamps. He will also learn to follow up a narrow deposit, with the hope that it will lead him to a broader expanse and more valuable deposit.

The search is also made more difficult by the fact that in places the coal has been cut out and removed since it was deposited. It is nominally covered with shale, once a soft mud, the fine material of which it is composed indicating that is was deposited in comparatively quiet water.

The coarse character of the sandstone covering the shales indicates that the materials composing it were brought in by water moving much more rapidly, and, we find by explorations, that in some places it had so much force as to cut away and remove the shales, and sometimes both the shales and the coal. Where a narrow channel was thus cut through the coal, and the material forming the sandstone was deposited in its place, a "horseback" is now found. There were local currents when the shale was deposited of sufficient force to cut away the coal and leave a "horseback" of this material. These may be struck in drilling and no indication of coal be obtained, while it may be of full thickness a few feet from the drill-hole. Where this active movement of the waters covered a wide area, the coals and shales may be removed from a large district, and the sandstone belonging above the coal be found upon the fireclay below the coal horizon. All these facts combined with the general topography of the county, affording few outcrops of the coal or of the coal shales, render the search for this coal uncertain and expensive. But it will ever remain the standard of excellence in Ohio coals, and the source of certain wealth to those who discover or control important deposits of it. This lower or block coal, designated as "Coal No. 1" in the Geological Reports of the State, is now extensively mined in Vienna, Liberty, Brookfield and Hubbard townships, these townships embracing much the larger part of the coal to be found in the county, and constituting one of the most valuable coal fields in the state. The daily product of these townships is now about four thousand tons, nearly all of which is strictly a first-class coal, superior to that from any other coal field in the state, the coals of the Mahoning valley being regarded as the same field, and having the same characteristics, and not excelled by any bituminous coals mined anywhere. The coal is generally remarkably free from sulphur and other

impurities, containing a small per cent. of ash and a large per cent. of fixed carbon, as the analysis of specimens taken from various openings and published in the chemist's report will show. It is generally a dry, open-burning coal, its mechanical structure causing it to take fire rapidly through the center of the largest pieces, especially adapting it to the smelting of iron. The coals of this valley were the first bituminous coals mined in the country for the reduction of iron ores without coking, a fact which made them widely known, and gave them at the time a reputation above all other bituminous coals. Notwithstanding continuous explorations have largely increased our knowledge of the coals of the country, and have brought to the notice of manufacturers many varieties of great excellence, these still maintain the reputation thus acquired. They are still the standard with which other iron-making coals are to be compared.

The surface of these townships exhibits an irregular series of gently sloping ridges and hills, in places three hundred feet above the valley of the Mahoning, and the coal is reached almost exclusively by shafting and slopes. The horizon of the coal is from forty to ninety feet above the valley, the floor of the coal being very irregularly waved; changes of level of forty to fifty feet sometimes occuring in very short distances. This rapid and irregular change in the horizon of the coal, is well exhibited by the explorations made by boring at the Brookfield Coal Company's slope in Brookfield township. The coal was first struck at eighty feet from the surface. Taking this point of the seam as a base, the other borings disclose the coal in the following positions, above and below this point:

1	$4\frac{72}{100}$ feet below.
2	$1\frac{45}{100}$ feet above.
3	$1\frac{90}{100}$ feet below.
4	$1\frac{02}{100}$ feet above.
5	$14\frac{86}{100}$ feet below.
6	$1\frac{12}{100}$ feet below.
7	$28\frac{38}{100}$ feet below.
8	$12\frac{50}{100}$ feet below.
9	$13\frac{50}{100}$ feet below.
10	$24\frac{18}{100}$ feet below.
11	$54\frac{80}{100}$ feet below.

These great irregularities in the position of the coal in one small coal basin, are more remarkable when this additional fact is considered, that at forty-two and a half feet above the block coal a thin seam (Coal No. 2)

was passed through in drilling the first hole, and that this coal maintained a perfectly horizontal position over the whole area, and was constantly found at an elevation of $45\frac{1}{2}$ feet above the point adopted as a base, so that in this one basin the distance between these two seams varies from $44\frac{5}{100}$ feet to $100\frac{3}{100}$ feet.

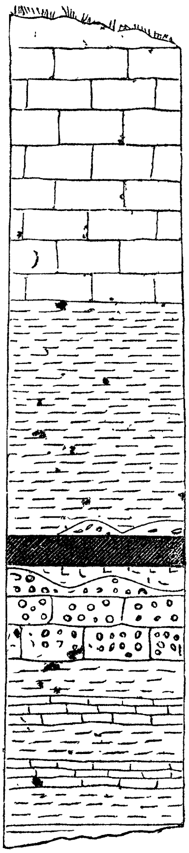
In these four townships there are between twenty-five and thirty slopes and shafts in successful operation. Among these, the following illustrate their general character. In Liberty township, the Niles Coal Company has a shaft one hundred and eighty feet to the coal, which is from three to four and a half feet thick; forty feet above the valley, is a typical block coal, finely laminated, free from sulphur, and of excellent quality. At the Briar Hill Company's new shaft, one and a half miles south-west from the center of Liberty, the coal is one hundred and thirty feet from the surface, three to four feet thick, of excellent quality. Ninety-five feet above the block coal there is another seam six inches thick, capped with shale and resting on a thin lime rock, the horizon of the iron ore of Hubbard township.

At the McCleary coal slope the coal is one hundred and ten feet from the surface, ninety feet above the Mahoning, two and a half to four feet thick; nearly exhausted. The coal is of good quality, but the seam is very irregular; roof in places shale, passing into sandstone and Conglomerate; and Conglomerate is also formed in patches below the coal. At the Mahoning Coal Company's bank, in Hubbard township, the coal is one hundred and eighty feet from the surface, sixty feet above the river, two and a half to four and a half feet thick. Horsebacks and irregularities in the roof are frequent; coal blue black; a good block coal, free from sulphur.

The general section, on page 500, compiled from the average of many drillings at Vienna, exhibits the relation of the coal to the including rocks in that locality. At Stewart's slope, in Hubbard township, this coal in the middle of the swamp passes into an impure cannel, which is rejected in mining. This cannel coal probably represents open water in the center of the old peat marsh, in which the finely comminuted carbonaceous matter became so largely mixed with earthy material as to make it worthless—the good coal representing the parts of the marsh where the peaty growth had encroached upon the water and filled the marsh.

COAL NUMBER TWO.

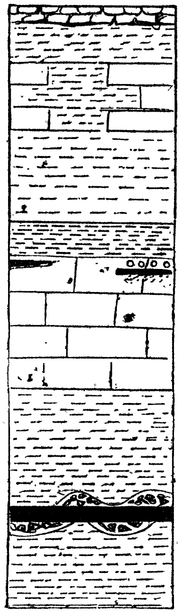
At an ordinary elevation of about forty-five feet above the block coal, is the horizon of another coal, which can be traced over a large area; and, although it is not of sufficient thickness to be worked in any part



of the county where it was observed, the iron ore associated with it renders it an important element in the mineral resources of the county. The irregularities in the floor of the lower coal render the distance separating these two seams a very variable quantity, ranging from thirty-five to one hundred feet, but it may be ordinarily sought for at an elevation of about forty-five feet above the lower coal. The general section of the Coal-measure rocks of the county, given on next page, illustrates its position and relations to the associated strata.

Coal No. 2 is not continuous over the coal area, and is ordinarily less than one foot in thickness. In Mahoning county, directly south of Weathersfield, and near the county line, it is a splint or semi-cannel coal, four feet thick, in two benches, with black bituminous shale below, and sandy shale above, containing large quantities of very good nodular iron ore. In this county the shales above it contain, in many places, the the same varieties of iron ore, and in places a compact bed of calcareo-bituminous iron ore takes the place of the coal. This has been mined in considerable quantities from John W. Loyd's ore bank, near the center of Hubbard, and used successfully for the production of iron by the Hubbard Iron Company. It is here a compact stratum eighteen inches thick, in cubical and oblong blocks, evidently containing considerable lime and bituminous matter. Specimens have been submitted to analysis, and the results will be found in the chemist's report.

It is covered by black bituminous shales, and is mined by drifting; in other places in the neighborhood by stripping. Its outcrop can be traced over a large area in this part of the county, in places becoming a strictly nodular ore, free from lime and bituminous matter, and will probably be employed much more extensively than it has been, in the production of iron.



Limestone, 3 feet to 4 feet.

Sandy Shales and Shaly Sandstone, with nodules of Iron Ore, 70 feet.

Black Bituminous Shale, 10 feet to 12 feet.

Coal No. 2, with thin beds of Fire Clay and Shale at Base.

Sandstone, 40 feet.

Shales 25 feet to 50 feet, with patches of Conglomerate at base.

Coal No. 1.
Conglomerate in patches, and occasional patches of Limestone.
Waverly.

On Robert Christy's land, one mile south of the center of Brookfield, this ore is the source of an important deposit of yellow hydrated oxide of iron, of unusual excellence and purity. It may be seen in many places in the neighborhood, but the most important deposit known is on Mr. Christy's land. Here it is four feet thick, over about one acre, and thence thining down or appearing in patches. The deposit is at the exit of a series of springs, on the horizon of Coal No. 2, and will continue to be deposited indefinitely as it is removed, unless the mining of the block coal, which underlies it at a depth of some forty or fifty feet, shall drain the sources of the springs. It is well adapted for use as a mineral paint, and has been used successfully, but to no large extent, for this purpose.

These varied deposits of iron on the horizon of this coal, indicate conditions similar to those under which bog and swamp ores are now deposited in our recent marshes. Iron was carried down in solution into the old carboniferous swamps, from the high lands surrounding them, and there deposited, and is now found as nodular, calcareous, or bituminous ore, according to the material mingled with it.

Although the Coal-measures occupy but a small part of the county, only a small per cent. of the coal and iron in that area has been mined. The thorough explorations now making, will increase the known quantity of these minerals, and render them of increasing importance to the manufacturing interests of the state. Compared with the cheaper, steam-pro-

ducing coals, the amount adapted to iron smelting is small, and true economy would dictate that these superior iron-making coals should be reserved exclusively for the use of the smelting furnaces.

THE CONGLOMERATE.

The Conglomerate which is so largely developed in Medina, Summit, Portage and Geauga counties, becomes comparatively thin in Trumbull county, and in places has entirely thinned out or has been removed. It is represented on the map by the irregular pink band along the northern edge of the Coal-measures, and is marked on the margin as No. 2. At Parkman, Geauga county, it attains a thickness of 175 feet, and in Newton township, is more largely developed than at any other place in Trumbull county, being thinner and interrupted towards the eastern part of the county. This is the great Carboniferous Conglomerate, which has been represented as a thick, massive stratum, underlying the whole of the coal regions, and as the salt-bearing rock of the interior of the coal territory of Ohio. It appears, however, to be a wedged-shaped formation, thinning out as it plunges under the coal rocks, or appearing only here and there in detached masses. The pebbly sandstone pierced by the salt wells of Tuscarawas and the neighboring counties, and which has been regarded as the Carboniferous Conglomerate, is undoubtedly Waverly, the southern equivalent of the Berea Grit, which over a large part of the centre of the state is a true conglomerate. Although this formation in northern Ohio contains ordinarily a profusion of water-worn quartz pebbles, the presence of these is not of itself sufficient to enable the explorer to determine that the rock containing them is in fact the true Carboniferous Conglomerate. Patches of coarse conglomerate with similar pebbles, are frequently observed in this county, above Coal No. 1, and precisely similar pebbles are sometimes seen in the Berea Grit, the horizon of which is about 100 feet below the Conglomerate. In fact, all the massive coarse sandstones of the Carboniferous and Sub-Carboniferous rocks, pass in places into conglomerate.

The location of this conglomerate is best determined by tracing its outcrop from point to point, although there are peculiarities which enable the explorer familiar with its characteristics to identify it precisely as he identifies the countenance of an old acquaintance, while it might be very difficult for him to put upon paper a description of the peculiarities which enable him to do so. It is generally more ferruginous and less micaceous than the sandstone above Coal No. 1. The enclosed pebbles are usually more numerous, larger, and more water-worn. The material is generally coarser and less firmly cemented; it weathers with

a more rounded outline, is more frequently broken up by long vertical fissures, and with proper care and patience there is little danger of a mistake in tracing it. When positively identified, it becomes a boundary which may be relied upon with implicit confidence, as the northern limit of the coal, and as a horizon, below which, a search for coal will certainly result in disappointment. Many thousands of dollars have already been squandered in this county, through ignorance or disregard of this fact; and if the survey of the county shall restrict explorations in the future to the horizon and limits indicated by the conglomerate, the amount thereby saved will exceed many fold the cost of the survey. As the actual outcrops of the rock are not continuous, its outline upon the map should be regarded as only approximately correct; as nearly accurate, but to be slightly varied at different points, as future and more exact examinations may require. If the explorer for coal will make himself thoroughly familiar with the characteristics of this conglomerate, he may save himself much neeedless expense, and will be able to expend his money in prospecting where there is at least a chance of success. The patches of conglomerate found above the coal in this county, contain finely comminuted fragments of shale, and can readily be distinguished from that which is Sub-Carboniferous.

The Conglomerate in many places, affords an inexhaustible supply of building stone, some of very superior quality. There is, however, comparatively little of it in this county which is valuable for this purpose, the best being suitable only for bridge and foundation work. The large amount of iron contained in it gives rise to frequent ferruginous springs, one of which in Howland is said to have proved a valuable remedial agent. Situated as it is in an attractive and romantic grove, "Howland Spring" has become a place of considerable resort during the summer months.

THE CUYAHOGA SHALE.

The Cuyahoga shale forms the surface rock in Braceville, Warren, Bazetta and Johnston, the larger parts of Weathersfield, Howland, Fowler, Vernon, Mecca and Gustavus townships, and smaller portions of Hartford, Lordstown, Champion, Southington and Mesopotamia. This surface is colored yellow upon the map. In Bazetta and Howland, excellent flagging stones are obtained from these shales, and in places the layers are thick enough to supply a stone for ordinary building purposes. Near Warren is a quarry in these shales, from which stone is obtained for paving the streets, and which is well adapted for this purpose, making a good and durable roadway.

The characteristic fossils of this formation are abundant in the county, and there are several places where the paleontologist can find much to interest him. In the bed of the Mahoning, west of Warren, the abundance of *Lingulæ* and the lithological peculiarities indicate that the stream at this point cuts nearly through these shales, and that the Berea grit is to be found at no great depth below. Here was obtained a very perfect and well preserved spine of *Ctenocanthus* (*C. formosa*), figured and described by Prof. Newberry in the paleontological part of this report. Near the west line of Vernon, layers of the shale are filled with a profusion of *Lingulæ* and a great variety of chambered shells, but the material containing them is so soft and friable that they cannot be well preserved. In the bed of the same stream, at a little lower level, beautifully preserved *Discinæ* are so abundant that slabs of a large size may be obtained, completely covered by them.

A little south of the center of Johnston, a shaft, sunk by the advice of some unknown parties, with the expectation of obtaining lead, shows that these shales extend to the top of the ridge, and are here sparingly fossiliferous. The merest tyro in geological science does not need to be informed that a search for lead, at such a place, could only lead to disappointment; but this is not the only place in the county where money has been expended in the search for minerals not to be found in the county or the state. Some years since, quite a large expenditure of time and money was made near Baconsburgh, in sinking shafts with the hope of obtaining silver, and during the first year of this survey, parties were met near Berg Hill, who were very much excited over the alleged discovery of silver in the Cuyahoga shale at that point—a valueless sulphide of iron, appearing in whitish metallic deposits on the shale, being the basis of the pretended discovery.

BEREA GRIT.

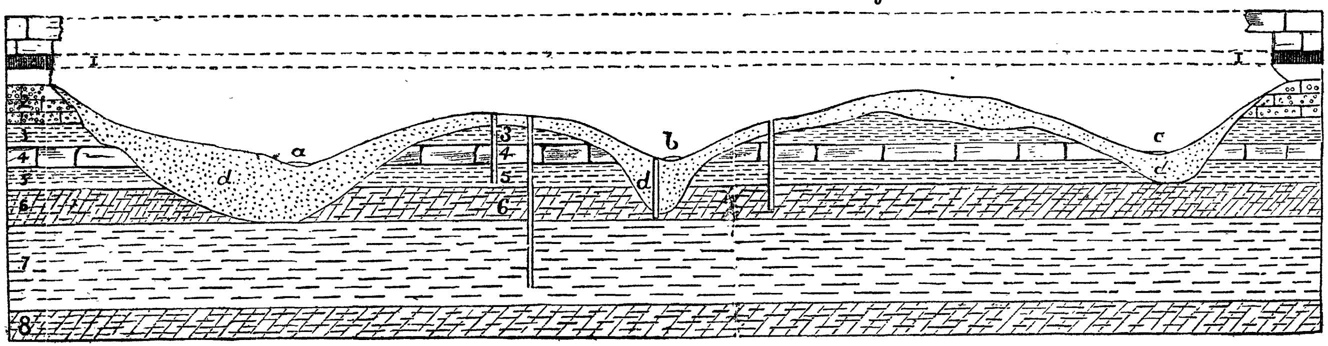
The Berea grit—the most important deposit in the eastern part of the State north of the coal fields—is of especial interest in this county, from the fact that, with the shales immediately below it, it constitutes the Mecca oil-bearing rock. It is designated upon the map by the narrow green line within the part shaded yellow, its position generally being accurately determined by outcrops and by the borings that have been made for oil. In Mesopotamia and Farmington, it is finely exposed, and much of it is a fine grindstone grit, which can be profitably used, in places, for grindstones and coarse whetstones. In both of these townships quarries may be opened, which will furnish good building stone in unlimited quantities. In Southington, Champion and Mecca townships, west of

Mosquito creek, the Berea grit is everywhere deeply covered by the clays of the Drift, and its position can be determined only by borings and the general topography. It can be accurately traced along both sides of the ridge passing through Johnston, Gustavus and Wayne. In Vernon, on the west side of the ridge, east of Pymatuning creek, it is exposed in massive layers, from which blocks of any desired dimensions may be taken. It is here firm and strong, but contains nodules of iron ore which will be likely to color the stone and detract from its value if used for building purposes. On the east side of this ridge it is, in places, filled with water-worn quartz pebbles, and might, upon a hasty observation, be mistaken for the Carboniferous Conglomerate, which caps the summit of this ridge. In the ridges on the east and west sides of Mosquito creek, it is usually soft and porous, and in many places is saturated with petroleum. This, and the Bedford shales underlying it, are here the oil-bearing rocks. Very many wells have been drilled for oil in Mecca and adjoining townships, on both sides of Mosquito creek—those on the west side being uniformly the most productive. Upon the ridge east of the creek, oil is found in nearly every well, but generally in small quantities, and in all the wells on both sides the supply is soon exhausted by pumping. The oil, however, again slowly accumulates, so that, after some months, the most productive wells may be again worked with profit.

The problem is here presented to the geologist to determine, if possible, why these rocks are more productive in oil than in other places in the neighborhood, and why the wells upon the west side of the creek are more productive than those upon the east side. To aid in solving this problem, the diagram and the facts which follow are submitted.

The highly carbonaceous shale, No. 6, is undoubtedly the source of all the oil here obtained, which, slowly separating from the shale, runs into the porous sandstones above. Wells sunk as at the four points indicated in the section, disclose oil in greater or less quantities in the formations marked 4 and 5; a strong odor of oil characterizes No. 6. If bored deep, as at the second from the left, no additional oil is obtained. On the ridges the rock is found in place near the surface, while in the valley, pipes are driven one hundred feet before striking the rock. On the east side of the creek, oil indications in the streams are abundant—more abundant than at any point on the west side. Many years before the value of the oil was known, considerable quantities were often disclosed in quarrying stone from the beds of the streams, and on both sides of the eastern ridge the Berea grit and Bedford shale come very near to the surface, their outcrop being exposed in many places, and in others covered only by a thin deposit of coarse

Profile Section across Trumbull County.



1. Former position (?) of the Coal No. 1.
2. Conglomerate.
3. Cuyahoga Shale.
4. Berea Grit—Mecca Oil Rock.
5. Bedford Shale—Mecca Oil Rock.
6. Cleveland Shale—First Oil-producing Rock.
7. Erie Shale.
8. Huron Shale—Second Oil-producing Rock.

a. Valley of Grand River, 420 feet below top of Conglomerate at Parkman's, and 320 feet below base of Conglomerate at Vernon. *b.* Valley of Mosquito Creek. *c.* Valley of Pymatuning Creek. *d, d, d.* Drift Clay.

gravelly soil. On the ridge west of the creek, there are no exposures of these rocks, and they are everywhere covered with a heavy deposit of compact impervious clay. On the one side there is nothing to prevent the escape of the oil, and it has doubtless for ages been slowly rising through these same rocks, seeping out at their margins, and has been carried away. On the other side it has been shut in by an impervious packing of clay, through which little of it could escape. The high table land embracing Geauga and parts of Portage and Summit counties, is underlaid by these rocks; but along their whole margin, upon the west, north and east, there is almost a continuous exposoure of them, where they are cut through by streams and ravines, so that they are thoroughly drained, and whatever oil may have issued from the shales has been carried away as fast as formed. No productive oil wells have been bored in that table land.

The excavating agencies, which have cut out, to so great a depth, the old beds of Grand river and Mosquito creek, carrying away the Coal-measures and the Sub-carboniferous rocks down to, and perhaps through, the Cleveland or bituminous shale, must have distributed and broken up, to a considerable extent, the oil-bearing rocks along these narrow ridges, thus facilitating the escape of the oil. This disturbance is shown by the exposure of a sharp, anti-clinal ridge near the center of Gustavus, where the surface rocks have a rapid dip, not as the result of an upheaval at the center of the ridge, for the strata quickly become horizontal on each side of the axis, but apparently the result of an immense force exerted horizontally on each side of the ridge. These oil-producing rocks, thus disturbed and broken, have been slowly giving out their products for unknown ages. Upon one side they have steadily escaped—upon the other they have been shut in and retained.

The lower oil-producing rock, marked 8 in the section, lies too deep to have suffered any disturbance from the agencies which have broken up the upper one. It is here not less than 1,200 feet from the surface, and probably retains its original horizontal, compact, undisturbed position, with no cavities in it, or the shales directly above it, into which the oil can flow and accumulate; and although a show of oil will generally be found wherever it is reached by boring, there is no probability that it will here afford any productive wells. The great supply of petroleum produced in Pennsylvania, is obtained from the deposit marked 8, or its equivalent; but the producing wells are along lines of upheaval, where it has been broken up and dislocated so as to facilitate the escape of the oil, and where, by the same agency, deep and extensive cavities and fissures have been found in which the oil can accumulate, and from which it cannot escape. There are no indications that the

lower oil-producing rocks in the Mecca oil region have been in any way disturbed, so that there is no reason to suppose that fissures and cavities have been formed, or that successful wells can be obtained at that horizon. The oil of Mecca is of superior quality for lubricating purposes, and commands a much higher price than the Pennsylvania oil, so that new wells may yet be sunk which can be worked with profit. But the largest supply of oil will probably be found near the surface, and in the clay lands between the valleys of Grand river and Mosquito creek, or along the center of the ridge between Mosquito and Pymatuning creeks, explorations being continued from the former towards Warren, and from the latter towards Vernon and Vienna, always seeking places where the surface drainage has not reached the Berea Grit and the Bedford shale.

BEDFORD SHALE.

North of the outcrop of the Berea Grit, the Bedford shales underlie the surface of the county, but are generally concealed by the Drift and alluvium, being exposed only in the branches of Pymatuning Creek, in Kinsman township. Here in Kinsman and extending into Williamsfield, Ashtabula county, these shales belonging below the Berea, are in fact interposed between two members of the latter. The Berea in Mesopotamia, is separated into two parts by about two feet of shale. On the eastern margin of the county, the upper part of the Berea passes out of the state near the north-east corner of Kinsman, the lower member passing along the higher ground, east of the Pymatuning, follows the course marked by the northern green line on the map, leaving the state somewhere near the northern part of Williamsfield, but is there covered with drift. It is exposed in several points near the old state road south of West Williamsfield; is there a coarse sandstone in thin layers, spotted with iron, and was used by the early settlers for grindstones. The lower part of the Berea is here comparatively thin and probably not of much economical value, although deserving of further exploration to test its extent and character. The intercalated beds are soft argillaceous shales with alternate hard bands. They contain large *Lingulae*, and other brachiopods, and exhibit the general characteristics of the upper portion of the Bedford shale. They are sometimes from 15 to 20 feet in thickness, accurate measurements of them not being possible. These shales ordinarily are composed in part of hard, firm layers, suitable for flagging stone, and in places of sufficient thickness for bridge and foundation stone, but over most of the county where they constitute the surface rocks, are too deeply buried under the Drift to be sought after for any purpose.

PEAT.

The extensive swamp in Bloomfield township, comprising several thousand acres, is evidently an old lake basin, now filled with a growth of peat. This varies in thickness from four to ten or more feet, covered in places with grass, mosses and cranberry vines, in others with a scattered growth of Tamarack and various small trees and shrubs. While wood is inexpensive and coal so cheap, it is not probable that this large supply of fuel will be utilized, but our peat beds constitute an important part of our reserve supply, to be brought into use when other fuels become expensive. If an immediate return from them is sought, they can be made of great value as fertilizers for partially exhausted soils, and there is little doubt that this is the best use that can be made of them. Properly composted and tempered by exposure to the air, a ton of this peat is nearly, if not quite equal in value, to a ton of barn-yard manure. As dug from the swamps, it is often saturated with acid, which renders it sour and arrests the process of decay, which is essential to the development of its fertilizing properties. When applied in such condition, it will produce no benefit, perhaps will impair the productiveness of the land on which it is spread; but if composted with lime or even exposed to the influence of the atmosphere for a few months, its great value as a fertilizer will be recognized at once by all who make trial of it.

CHAPTER XIX.

GEOLOGY OF LAKE COUNTY.

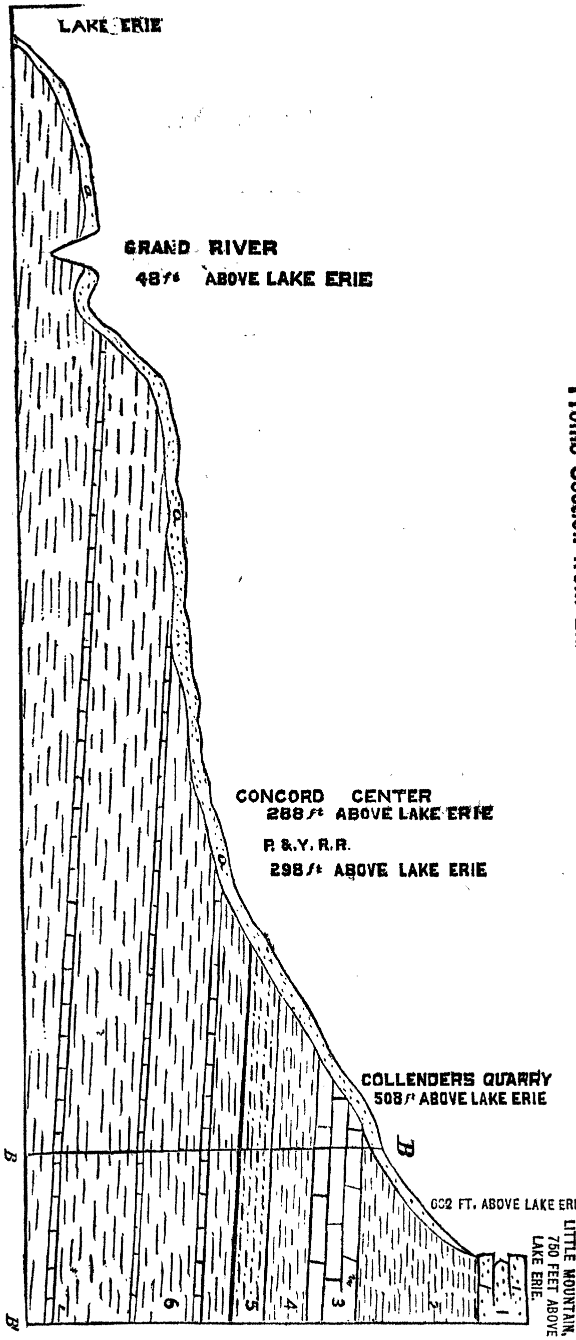
While great inequalities characterize the topography of this county, they are due entirely to erosion. The general surface is an almost uniformly inclined plain, rising gradually from the lake to an altitude of over 600 feet at the base of the conglomerate wherever it strikes the south line of the county. This feature of the topography, as well as the geological structure, is shown in the accompanying profile section.

That portion of the section included between A and B, exhibits the outcrops of the different strata between the Lake shore and the south line of Concord. It also exhibits the general aspect of the slope that has been referred to, but the angle of inclination of this has necessarily been greatly exaggerated. The point B, in the section on the south line of the county, is 528 feet above the Lake level, and about nine miles distant from the shore. Here the Berea Grit, the outcrop of which is soft and shelly, comes near the surface. The shales below are soft, and have no interstratified bands of hard rock, which offer special resistance to eroding agencies. Upon such a geological substructure, the slope to the Lake could not fail to be quite uniform, except where modified by surface drainage, but with an average descent of 58 feet to the mile, the smallest streams have great eroding power, and they have here made a net-work of irregular hollows and ravines, which everywhere mark the surface.

The continuation of the section B to B', represents the remainder of the ascent to Little Mountain, where it terminates with the Carboniferous Conglomerate. As soon as the Conglomerate is reached, the fact is revealed by the topography, although the rock itself may be entirely covered with drift. The conglomerate is generally massive, and offers such resistance to denuding agencies that an abrupt ascent marks its outcrop. The wide, vertical fissures which penetrate it, form long torturous channels, which render the surface hilly and broken.

At Little Mountain, recent surveys show that the top of the Conglom-

Profile Section from Lake Erie to Little Mountain.



VERTICAL SCALE, 1 INCH TO 300 FEET.

1. Conglomerate. 2. Cuyahoga shale. 3. Berea grit. 4. Bedford shale. 5. Cleveland shale. 6. Erie shale. *a, a, a.* Drift clays.

erate is about 750 feet above the lake. Its northern outcrop here forms precipices or precipitous bluffs, about 70 feet high. The upper surface is comparatively level, and large granite bowlders are scattered over it. Fissures here penetrate the rock to the bottom, dividing it into immense blocks, which have a very thin covering of soil. On the southern part of the mountain, the Conglomerate is much broken up, and the soil is deeper, though mingled with fragments of the pulverized rock. The vegetation which covers the surface marks the change. At the north end of the mountain coniferous trees—hemlocks and pines—almost exclusively compose the forest. In all such positions these are the pioneers which aid in the preparation of a soil fitted for deciduous and fruit-bearing trees. Drawing comparatively little sustenance from the earth, they flourish where other plants would starve, and by their growth and death through successive generations, by disintegrating the surface rock and producing an accumulation of humus, they produce a soil which in time becomes unfit for their use, and better adapted to the support of more highly organized plants which now come in and take possession. Southward upon this narrow ridge, chestnuts and rock-oaks appear, and where the soil is best, these have entirely excluded the coniferous trees.

Pierson's Mountain, near the east line of Kirtland, is the most northern extension of the Conglomerate in that township. It is a small circular knob, having essentially the same elevation as Little Mountain, broken on the surface and covered with a dense growth of young chestnuts. Elsewhere in the township, the denuding agencies have cut away and removed the upper portions of the Conglomerate, so that it is comparatively inconspicuous.

CUYAHOGA SHALE.

The Cuyahoga shales are fully exposed nowhere in the county, but the topography indicates that their thickness is about 180 feet. They constitute the surface rock between the Conglomerate and the Berea grit, and if uncovered might afford, in places, material for fair flagging stone.

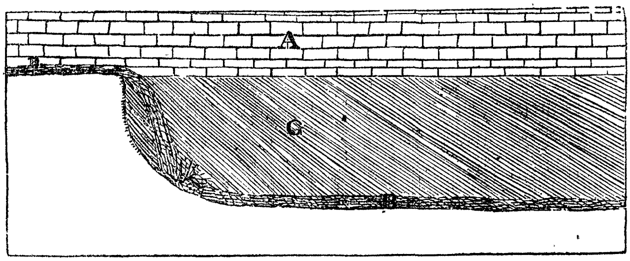
BEREA GRIT.

This coarse sandstone, exhibiting a sharp transition from the shales above and below it, has its usual thickness and characteristics in LeRoy, Concord and Kirtland, though covering only a part of these townships. Its northern limit is generally marked by a conspicuous belt of sandy soil. Its outcrop enters the county in the south-east part of Kirtland, extends northward about two miles, thence turns eastward through the center and near the east line of the township, and bending southward

along the bluffs of the east branch of the Chagrin river, passes into Chester and Munson townships of Geauga county. It again enters the county near the south-west corner of Concord, and can be traced entirely around Little Mountain, its upper surface being about 180 feet below the base of the Conglomerate bluffs. It again enters Concord east of the Painesville and Youngstown railroad, and caps the high land south of Concord Center, on which Callender's quarry is opened. It also covers the high lands about Hill House P. O., in LeRoy township, and is fully exposed a little to the east, at the Plankroad Mills on Paine's creek. It has been quarried to some extent for bridge building in the south part of Concord, but only the upper layers have been explored, and these have not yielded good building stone. Where the quarry has been opened, drainage is difficult, and the stone must be transported in wagons. As the same ledge can be struck on each side of the railroad, near the south line of Concord, and at an elevation of about thirty feet above the track, it is obvious that there is the place to open and work quarries most successfully. By drifting into the hill at the base of the Berea, drainage will be easy, the whole ledge will be exposed, and if it contains layers suitable for building purposes, they can be made available. There is certainly a demand in the county for the coarser grades of stone for bridges and foundations, such as to justify the opening of quarries at this point, even if stone of strictly first class quality should not be obtained; while it is highly probable that stone of a much better quality than that exposed in the Callender quarry, will be uncovered in some part of the ledge. North and north-west of Little Mountain, the outcrop of this rock is mostly covered, and the upper part of it is apparently cut away over a large area, a belt of sandy soil marking its position, and extending evidently to the north of it.

In Kirtland, from eight to ten feet of the upper part of the Berea are exposed in quarries. The surface layers are thin and very much ripple marked, while the lower ones are more massive, though much broken, the layers varying in thickness from ten inches to three feet. The rock is firm and strong, but irregularly colored. In some places in the township, oblique lines of cleavage render parts of the rock worthless, as in the following section, where these cleavage lines cause a small cascade to be formed on a little stream south-west of the quarries.

In this section A. represents thin horizonal layers of the Berea, B. B. B. the bed of the stream, and C. oblique layers dipping on the left, as exposed, at an angle of 45°, and changing rapidly on the right of the section, or to the north-east, toward a horizontal position, the line of the strike being north-west and south-east. Careful observations of these



Oblique Stratification of Berea Grit.

oblique lines of stratification would probably enable us to determine the direction over large areas of the currents which brought in the materials of this rock. Exposures in this stream below, show that the Berea has here a thickness of sixty feet, of which about forty feet are in firm, hard layers, ranging in thickness from ten inches to three feet, and giving promise of stone of good quality, if quarries were opened through all the layers.

BEDFORD SHALE.

The best exposures of the *Bedford Shale* are in the deep gorge west of the center of Kirtland, but their position, as underlying the Berea, can be easily traced throughout the southern parts of the county. They are here forty feet thick, composed mostly of hard compact rock, in thin layers, from one to thirteen inches in thickness. Eastwardly in the county, they become softer and more aluminous, and for the most part are covered with Drift and soil.

CLEVELAND SHALE.

The Cleveland or Black Shale presents the same characteristics as in Ashtabula county. The upper thirty feet, as exposed in the gorges in Kirtland, being a typical bituminous shale, which passes by a gradual transition through thirty-five feet, into the Erie shales below. This constitutes the lowest member of the Lower Carboniferous rocks. The plants imbedded in it sometimes have a thin coating of true coal, and the whole mass contains a large proportion of bituminous matter. Were the inclined plain, which extends from the base of the Conglomerate to the lake, not cut up with ravines, as the effect of erosion, the line of division between the Lower Carboniferous rocks and the Devonian below, would be a very regular curve from near the south line of Madison township to a point about two miles north of the south line of Willoughby township, and everywhere about 350 feet above the lake. As it is, the Erie shales are disclosed in all the deep gorges made

by the streams, to points two, three, and, in places, four miles south of this line. The green shading on the map designates the parts of the county where these Devonian shales constitute the surface rock. These deep gorges afford many exposures of these shales, so that the characteristics of the entire mass above the lake can be easily and minutely studied. They exhibit a great uniformity in their lithological characteristics, the whole mass consisting of blue, friable, aluminous shales, with occasionally thin bands of hard, calcareous sandstone. These are broken into blocks by irregular vertical seams, and frequently contain nodules of iron ore, profusely marked upon the under sides with the casts of fucoid plants, but being of very little economic value. Some of these bands, as in Ashtabula county, occasionally pass into a true limestone, and give origin to deposits of calcareous tufa on the slopes below.

HURON SHALE.

Below the Erie shales, which are from 700 to 1200 feet in thickness, (according as more or less of the upper portions have been cut away,) are the *Huron Shales*, the source of the gas which has been obtained by borings at various points along the lake shore. From some of these wells, an abundant supply of gas has been obtained, as soon as these shales were pierced; at others little, and in some, none whatever. At Painesville and Conneaut a copious supply has been obtained, but at Ashtabula the search has not yet proved successful. At this latter point, Mr. P. H. Watson is making a persevering experiment, and his well is now at a depth of 870 feet, the last 25 feet being in the Huron or gas producing shale. But little gas has, however, as yet been obtained. In Harpersfield and Andover, Ashtabula county, large quantities of gas have flowed from wells sunk in the Erie shale, but undoubtedly from cavities leading down to the Huron shale. This gas has the same origin as petroleum, and the search for it is subject to the same conditions and hazards. One drill hole may pass through compact, unbroken layers of the shale, piercing no cavities or fissures, and no gas is obtained. Another, near it, striking such fissures, may yield an abundant supply of it, results which no study of the surface would enable the explorer to predict. When in deep wells no sufficient supply is found, the explosion of torpedoes in the bottom of the boring, may open up a passage to neighboring fissures, and produce satisfactory results. No well should be abandoned as a failure, without a resort to this expedient, as it will doubtless, occasionally secure success in wells which would otherwise prove failures. Under all circumstances, the result will be uncertain. In places nothing will be obtained, and doubtless many wells, at first yielding an abundance, will gradually fail and become useless.

SOIL, DRIFT AND LAKE RIDGES.

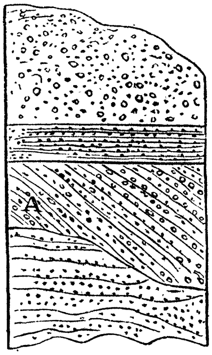
The whole surface of the county covered by the Erie shale, is greatly modified by the drift, and by the shore deposits of the lake. In Willoughby township, north of the old Chardon and Cleveland road, the soil is clay, surface level with forests of beach, maple, oak, hickory, &c., with many large elms. The Lower Carboniferous shales come near to the surface, and their debris forms the greater part of the surface material north of this road, until the old lake beaches are reached. The soil is stiff clay and the surface much eroded, deep ravines cutting down into ths Erie shales, giving good surface drainage and producing conditions admirably adapted to fruit growing. Granite bowlders are sparingly scattered over the surface. The southern lake ridge here and in a large part of the county, is mostly composed of unstratified clays, but is irregular and not well defined. In places, it is largely composed of gravel, and much of this is stratified. The rapid rise from the lake, renders it probable that high bluffs marked the south shore when the water stood at the elevation of the outer or southern ridge, and that after it receded, erosion so modified the surface as to cover the old shore line with the debris of the bluffs, then forming the ridge, and so masking its position. The blue and yellow clays cover the shales to the present lake level. In nearly all the northern part of Willoughby and Mentor, the surface is covered with a fine clay loam, containing little sand, and in places covered with a dense forest of elms and black ash, indicating areas long occupied by shore swamps. The relation of the yellow and blue clay, to the present surface of Chagrin river, at a point about three-fourths of a mile north of Willoughby village, is shown in the following section, the clay being wholly unstratified:

Yellow clay, 12 feet.
Blue clay, 25 feet.
Bed of stream.

The clay contains a profusion of granite bowlders, marked by glacial striae. About four feet above low water in the stream, a fragment of wood about eighteen inches long and four inches in diameter, worn to an elongated elipsoidal form was imbedded in the blue clay, in such a position that it must have been deposited there with the clay. This is the only fragment of wood I have seen in such a position.

At Painesville, the south ridge is in places largely composed of coarse, stratified gravel, but it has been modified by subsequent action. The

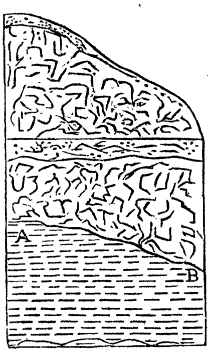
following is a section from a cut made by the P. & Y. R. R., on the north bank of the river:



Section of South Ridge, at Painesville.

The part marked A, appears as if it took its present form from a slip to the north of a gravel bank, beginning with horizontal lines of stratification. This part, A, is here and for a considerable distance east and west, cemented by lime, coming down from the gravel above, into a conglomerate, so hard and firm that it can be removed only by blasting. In places where it is undermined by the removal of the underlying gravel, it falls down in irregular masses, from which fragments can be broken by a hammer with difficulty.

Section of South Ridge, East of Painesville.

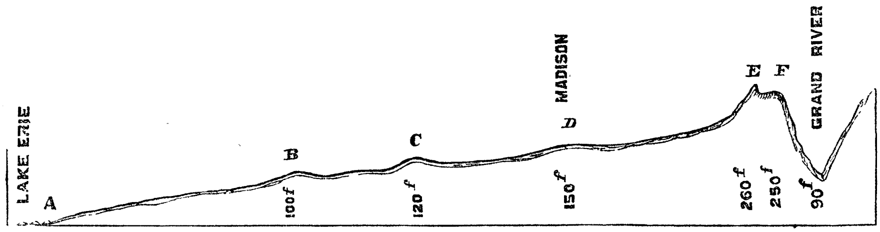


East of Painesville a sharp bend in the river makes a cut at right angles through the south ridge, where it has evidently been undisturbed, and although the slope is partly covered with debris, the section here given, can be made out.

From the amount of debris covering the slope, it appears that the materials belonging above are washed down into that below, so that the arrangement of the sands and clay of the ridge is somewhat obscured. The fact of special interest is this: that at the point B, about fifteen rods from A, the latter point being to the south, and directly under the crest of the ridge, the shales are cut away to the depth of twenty feet lower than at A.

In Madison township the slope from the lake rises more gradually than further west, and the lake ridges are more regular and are better defined. The following is a profile section from the lake through Madison center to the bed of Grand river, which, at a distance of a little over six miles in a direct line from the lake, is ninety feet above it:

Profile Section from Lake Erie to Grand River.



HORIZONTAL SCALE, 1 INCH TO 1½ MILES.

The bluff of the river is 250 feet above the lake. An irregular clay ridge, half a mile north of the bluff, and about five and three-fourths miles from the lake, is here the most southern well-defined lake beach. It is 260 feet above the lake, and composed of bowlder-clay, with a surface somewhat irregular from the effects of erosion, but gently sloping to the sandy ridge D, on which Madison village stands, the surface generally becoming sandy as this ridge is approached. From this point there is a rather rapid descent to the level of the railroad, the incline beyond being so gradual that the surface appears quite level until the gravelly ridge C, is reached. The surface between D and C has generally a loamy, gravelly, clay soil. The northern part, a little below the level of the ridge C, in places is somewhat swampy. A few scattered dunes and billowy sand ridges may be seen south of C. The general slope from B to C is very regular, but the surface is much diversified by sand dunes and stretches of marshy land, some of it too wet for cultivation and drainable with difficulty. The ridge at B is made of fine, water-washed and drifted sand, and the slope thence to the lake is of similar character, somewhat diversified by windrows of sand. This sandy slope terminates at the lake; the lake beach being composed wholly of washed sand. The north ridge B, continues from Madison to Painesville, and consists of irregular sand dunes, constantly changing in form under the influence of the wind, and frequently containing so little vegetable matter as to be almost entirely barren. Where undisturbed, it is from ten to twelve rods wide, with a gentle descent on each side, but sloping most rapidly towards the north. On the north side of this ridge, east from Painesville, is an extensive deposit of peaty material or black muck, with a maximum thickness of six feet, and filled with the roots and trunks of tamarack

and pines. This old marsh was in places 100 rods wide, with a bottom of mingled sand and clay. The nurserymen and market gardeners have found in this muck a very excellent fertilizer, and are making an extensive and profitable use of it. Very many interesting problems are presented in regard to the relations of the drift clays and the old beaches and ridges of the lake, but the facts which can be collected in the brief time given to the survey will hardly suffice for their solution.

Three and a half miles west of Fairport is a deep, broad channel of an old river, evidently much larger than the present Grand river, with abrupt banks on each side, which at the lake are over one mile apart. The intervening marsh is quite level, and contains stretches of open water from eighteen to twenty feet deep. At the lake shore is a sand bar, stretching from one bluff to the other, through which the included waters occasionally cut channels and flow out in a rapid torrent. This old river bed turns to the east, and is continued with bluff banks nearly to the present channel of Grand river, where it is so filled up as not to be easily recognized. The depth of this channel below the present surface of the lakes has not been determined. It has doubtless been the outlet of a river since the lake occupied its present level, and how far in the past its history is to be carried, can be determined only by further explorations.

FOSSILS.

Nearly all exposures of the rocks examined in the county were nearly barren of organic remains of any special interest. In the bed of Paine's creek, in the north part of LeRoy township, several small nodules were found in the Erie shale, from which specimens of a new crustacean and various shells were obtained. Further research will be made at this point, with the hope of securing much that will be of special interest to the paleontologist.

CHAPTER XX.

GEOLOGY OF GEAUGA COUNTY.

TOPOGRAPHY.

The geological formations of Geauga county, while simple and easily understood, afford an interesting example of the manner in which the geology and topography of a country determine the pursuits of the inhabitants, and the boundaries of separate communities. A line defining the western, northern and eastern limits of the conglomerate, defines also the western, northern and eastern limits of the county, as accurately as it could be laid out without dividing townships. These boundaries were fixed with no reference to the geology, but the latter has formed the tastes, determined the pursuits of the inhabitants, and grouped them into a civil community.

The same causes have so determined the direction of the water courses, that after a little examination of the county and the adjacent territory, the student of its geology will find that an ordinary map will designate with great accuracy the limits of the conglomerate, which is the characteristic feature of the elevated table land comprising the county. The Cuyahoga and Grand rivers, and the streams emptying into them above Cuyahoga Falls and Parkman, will be found in every instance to have their sources and beds on or above the conglomerate. All other streams in the county have their sources below the conglomerate, or so near its margin, if above it, that the general southern inclination of the rocks is counteracted by the agencies which have thinned down or cut into ravines the outer margin of this deposit.

The waters of these streams also differ greatly. Those above the conglomerate, having their sources in swamps and ponds, are rendered foul and turbid by the vegetable and animal remains, with which they are charged. Those of the others derived largely from springs at the base of the conglomerate are thoroughly filtered; are freed from organic matter and rendered clear and sparkling, but are often charged with minerals, especially iron, sulphur and lime.

SOIL.

The debris of the clay shales, mingled with the drift, has formed the basis of a strong, tenacious clay soil, especially adapted to grazing, and the county has from this cause, and not from the choice of its inhabitants, become noted for the excellence and abundance of its dairy products. The elevated position of the county, added to the peculiarities of the soil, has especially fitted it for the production of fruits, particularly of apples, pears, quinces and grapes, and these are now largely cultivated, notwithstanding the isolated position of the county, and the want of all means of transportation to market, except the ordinary carriage roads. Were it connected by railroads with the larger markets of the country, fruit-growing would soon become the principal business of its inhabitants.

GEOLOGICAL FORMATIONS.

COAL-MEASURES.

In the center of the county a narrow and thin deposit of the coal-measures caps the hills along the east bank of the Cuyahoga, extending from the south line of the county to the point where that stream curves around to the north of Burton village. This deposit crosses the Cuyahoga, underlies Burton village, extending to the northern part of the township, with an isolated patch at the north-east corner of Newberry township. In no part of the county is there a promise of any important amount of coal. In Troy township the coal-measure sandstone is separated from the conglomerate by the coal shales, which are in places very thin and rarely exceed a thickness of six feet. In the southern part of the township coal has been obtained in small quantities from a seam too thin to be profitably worked, yet at this point it is probably thicker than in any other part of the county east of the Cuyahoga. At Burton the coal shales and the seam of coal are thicker, the rocks of the coal-measures reaching a thickness of one hundred and twenty-five feet; and if the village is to remain without railroads, further explorations of the coal seam by shafting or drifting are advisable, as there are indications of coal in sufficient quantities to be profitably mined for local consumption. There is, however, no promise of a supply sufficient to warrant its shipment elsewhere, or to enable the owners to compete with coal from the more productive coal-fields of the State, if the latter could be brought in by railroads.

Near the north east corner of Newberry township, coal of very good quality about two feet thick, has been disclosed in sinking a well on Mr. Frank Stone's farm, and at a depth of about ten feet from the surface.

A thin stratum of shale covers the coal, not thick enough to constitute a safe roof, but to the west and northwest, the surface of the land rises, and, over a small area, it is possible a sufficient cover may be found so that the coal may be taken out. The quantity, however, is not large, and what coal there is must be sought near the summit of the hill. A series of springs may be seen low down in the ravines, and the opinion is entertained by some of the land owners,—derived apparently from parties who have taken coal leases,—that these springs are on the horizon of the coal, and that it will be found by drifting in at this level. But these springs are either in or at the base of the conglomerate, which crops out at several places on the hill at a higher level, and all the coal there, must be sought for above this rock. This is the lower coal seam, and here is the extreme northern limit of the Coal-measures of the state.

CONGLOMERATE.

Below the Coal formation, lies the conglomerate or pebbly sandstone, varying in thickness from sixty to one hundred and seventy-five feet. In places it is separated from the coal shales by layers of shaly sandstone, which reach a maximum thickness of twenty-five feet, but are often much thinner and sometimes entirely wanting. In places, also, the coal shales thin out and disappear, as at Troy Centre, where the Coal-measure sandstone, rests directly upon the shaly sandstone of the conglomerate. Both of them contain at this point, a profusion of calamites and are in places so ferruginous as to constitute a silicious iron ore.

The conglomerate underlies the whole surface of Auburn, Troy, Newbery, Burton and Claridon townships, and crops out in all the other townships of the county, the deeper ravines cutting through it and exposing the rocks beneath. It differs greatly in its character in different places, sometimes affording excellent building material, and elsewhere being quite worthless for building purposes. Some of it in Russell township, is fine-grained, hard, of a clear white color, and in all respects an excellent building stone. In the northwest part of Chester, ledges are exposed from 30 to 50 feet in thickness, which are throughout a mass of white quartz pebbles, with loosely cemented sand, filling the interstices. These pebbles might possibly be made valuable for glass making and for pottery, as they could be obtained in large quantities, and at a trifling cost. At the base of this ledge, which is rapidly diminishing under atmospheric influences, the debris is exposed to the action of water containing iron and lime in solution, and is thus re-cemented into a much harder rock than the cliff from which it is derived. In this debris, recent organisms and modern implements might easily be covered, fossilized and preserved, to be hereafter studied as a part of the records of this age. Specimens gathered

from similar localities, by those who are not careful and accurate observers, might lead to very erroneous conclusions as to the age in which they were deposited.

In Newberry township, this rock is in places handsomely colored by oxide of iron, but at the out crop is coarse and soft. Should there be a sufficient demand to warrant thorough explorations, it is probable, colored rock suitable for ornamental building might be found there.

In Parkman, the conglomerate attains a thickness of one hundred and seventy-five feet, being the maximum thickness of this rock, where measurements have been made in north-eastern Ohio. Here much of it contains pebbles but the most is so free from them as to make a fair, building stone, and the supply is inexhaustible.

In Thompson, the well known ledges furnish a fine exposure of this rock, and give a rugged and romantic character to the place, which attracts many visitors during the summer season. The dip here is 4° to 5° to the southwest.

"Little Mountain," situated partly in Geauga and partly in Lake counties, is an isolated narrow ridge of the conglomerate, having an altitude of seven hundred and fifty feet above Lake Erie; covered with a forest of pine, hemlock, oak and chestnut; cut into deep ravines, with precipitous bluffs on the north and west. The altitude of Little Mountain renders the air cool and healthful; its isolated position affords a commanding view of the surrounding country and of the lakes; its dense forest furnishes pleasant walks and drives, so that it has naturally become one of the most popular places of resort in the state. Chalybeate water of excellent quality, is furnished by the springs at the base of the mountain, but the want of water in sufficient quantities for bathing is a serious inconvenience.

BEREA GRIT.

The denuding agencies have so cut away the rocks about the mountain, that the Berea Grit may be found on all sides of it, and at no great distance from it. It appears by the side of the road about one hundred rods from the mountain on the main approach to it, and is quarried on Chardon road about half a mile south.

This Berea Grit is to be found at an average depth of one hundred and eighty feet below the conglomerate, and is the most valuable building stone in the county. Its outcrop may be traced through the west part of Russell and Chester townships, through the west, north and east parts of Kirtland, Lake county, extending up the valley of a branch of Chagrin river, into Munson township, through the west and north parts of

Chardon, through the west and north parts of Thompson, and in the north-east and south-east parts of Parkman townships. In other places its outcrop is outside of the limits of the county.

At nearly all of the points indicated above, it may be found massive and of good quality for building purposes. In Munson a quarry has been opened, which, by proper selection, affords stone of excellent quality, and from which material was obtained for the new court-house at Chardon. A few of the blocks in this structure will probably prove defective from being placed on their edges, and not in the position in which they were found in the quarry. In Chardon, in the "Big Gull," and at the north-east corner of the township, the Berea grit is finely exposed, and in both of these places there is a large part of it which will make grindstones equal to the best made at Berea.

In Thompson, north and west of the "ledges," it is quarried in several places, the quarries furnishing excellent flagging, and also strong, firm slabs of any desirable size, and from eight to twelve inches in thickness. At the bottom of the layers quarried, is a stratum of very soft, friable stone, of no value, which on exposure crumbles into sand. It is probable that below this the rock will be found massive and of better quality. The quarries may be extended indefinitely by drifting toward the "ledges."

While this formation affords a great abundance of excellent stone, its character varies greatly, as the following sections will show:

Section No. 1.

Compact sandstone, in two layers	8 feet.
Shaly sandstone, lines of cleavage horizontal	7 to 8 feet.
Shaly sandstone, lines of cleavage oblique and curved	6 feet.
Shaly sandstone, lines of cleavage horizontal	4 feet.
Shaly sandstone, lines of cleavage oblique	8 feet.

No. 1 is a section of the Berea, near the south line of Russell township and east of Gates' Mills, on Chagrin river. The upper part of the Berea has here been cut away. Nearly all of the thirty feet remaining is soft and friable, in very thin layers, much of it with oblique lines of cleavage, and of no value whatever.

Section No. 2.

Shaly sandstone, in thin layers	8 to 10 feet.
Blue shale	½ to 1 foot.
Sandstone, in layers from 8 inches to 2 feet	6 to 8 feet.
Massive sandstone, in two layers	10 to 12 feet.
Sandstone, in thin layers	8 to 10 feet.

No. 2 is a section of the quarries in Munson township which contains much valuable stone. Other sections might be given which would repeat in varying order the peculiarities of these two, while in some exposures nearly the whole layer is hard and massive. The transitions in character are often quite rapid, and oblique lines of cleavage frequently change in a short distance to a horizontal position.

It will thus often happen that exposures which are quite unpromising will, on thorough exploration, lead to stone that is hard, massive, and of good quality.

CUYAHOGA SHALES.

Between the Berea grit and the Conglomerate lie the Cuyahoga shales, which are exposed in but few places in the county, and as far as observed, afford no valuable minerals. Their position is generally marked by a belt of heavy clay land, nearly level, extending outward from the base of the Conglomerate; when covered with forests, supporting many gigantic elms, and making excellent meadow and pasture lands when cleared. They are reclaimed with difficulty, as a dense growth of shrubs, brambles and weeds springs up everywhere, as soon as the forests are cut down, and the soil is generally too wet, until drained for grain crops. The eastern portions of Huntsburgh and Montville afford illustrations of this kind of soil. No part of the county presents a more uninviting appearance, and no part of it affords richer pasture lands than these will become when fully reclaimed.

BEDFORD SHALES.

These lie directly beneath the Berea grit, are in this county from forty to fifty feet in thickness, and are exposed only in the ravines formed by the branches of Grand river and the Chagrin. They include layers, from one to three feet in thickness, of compact fine-grained sandstone, susceptible of polish, and which would make excellent window caps and sills if properly selected. They contain iron, which will "run" (in the language of the masons) and color the stone, unless care is taken to reject imperfect specimens. Some of these layers would furnish material for fine-grained grind-stone and oil-stones; those near the north-east corner of Chardon being of the best quality seen in the county.

CLEVELAND SHALES.

Below the Bedford shales, these ravines cut through about forty feet of the Black or Cleveland shales, and below this the branches of Chagrin river, in Chardon, expose something over one hundred feet of the Erie

shales, the lowest rocks to be seen in the county. Neither of these deposits furnishes materials of any economic value, but if the supply of petroleum from wells should fail, the Black shale would become valuable from the amount of oil it will yield by distillation.

FOSSILS.

Comparatively little interest attaches to the organic remains found in the county. In the ravines in the north part of Thompson and Chardon, which cut through the Bedford and down into the Erie shales, large numbers of brachiopods, characteristic of these rocks, are found; *Syrongothyrus typa* in the former, and *Spirifer Verneuilie, Leiorhynchus multicosta*, etc., in the latter. In the Cuyahoga shales, north of Chardon village, an outcrop in the travelled road furnishes many perfect specimens of *Discina Newberryi.* In the Conglomerate, an abundance of *Calumites* occur, and in the limited area covered by the coal shales collections may be made, in moderate quantities, of the plants characteristic of the lower or block coal.

Since the above was written, parties in Montville, in excavating the peaty material from a small marsh, fell upon a part of the remains of one of our extinct elephants, the occurrence causing quite an excitement in the neighborhood, and leading to the hope that the entire skeleton might be recovered. The remains were obtained from a small marsh, which had apparently been an open pond with a clay bottom, and which had been slowly filled from the growth of swamp vegetation; the remains being obtained from the clay at the bottom of the marsh. The two tusks, the point of each broken off, evidently while the animal was alive; all the bones of the pelvis, seven or eight vertebræ, a few ribs and fragments of ribs, a part of a radius, a few fragments of the facial bones and part of one tooth, comprise the remains yet discovered. The tusks are remarkable for the regularity of their curve and for their almost uniform diameter throughout. The form and proportions of one of these tusks would be substantially represented by an arc, of which the chord was six feet in length, and the distance from the middle of the chord to the middle of the arc fifteen inches. The diameter of the tusk, at the point of insertion in the jaw, is three and a half inches, slowly increasing to four inches at a point about two feet from the base, and then tapering very slowly to the broken extremity, where it is three and one-fourth inches. The largest perfect rib is three and a half feet long, though a broken one, too friable to be preserved, is reported as four feet eight inches. A part of the ribs are remarkably expanded distally, being sabre-shaped, and the

flattest one measuring five inches at the widest part. The remains are probably from a young individual of the *Elephas Americanus*.

SURFACE DEPOSITS.

The most interesting surface deposit is on the farm of John R. Smith, lot 4, Auburn township, a deposit of black oxide of manganese or wad, of sufficient purity and in sufficient quantities to be dug and shipped with profit. It covers from three to four acres of swampy ground, fed by copious springs, which bring in, in solution, manganese, iron and lime, and deposit, in different parts of the swamp, bog manganese, bog iron ore and bog limestone, or *travertine*, the latter being found in places two feet in thickness. These three minerals are deposited in comparative purity in different parts of the swamp. The manganese is in places four and a half feet thick, covered with from twelve to fifteen inches of earth, and sells readily for from seven to thirty dollars per ton, according to purity. The process of deposition is going on constantly, and in the summer months with a good degree of rapidity, so that parts of the swamp which have once been stripped, fill up anew and can be re-worked after a few years. According to Mr. Smith's observations, the average rate of deposit is a fraction over two inches per year. This rate could probably be increased by shutting off the flow of surface-water into the swamp, and isolating the water coming from the springs charged with manganese.

In the neighborhood of the swamp are many small deposits of impure yellow ochre, some of which may prove of value.

Prof. Newberry supplies the following formulæ of the chemical composition of the best specimens of this manganese:

No. . Air Dried.

Oxide of manganese	61.85
Silica, alumina and iron	23.60
Water	14.00
Total	100.00

No. 2. Dried at 250° Fahrenheit.

Oxide of manganese	72.38
Silica, alumina and iron	23.60
Water	4.02
Total	100.00

The small swamps contain shallow deposits of impure peat or black muck which may be used as a fertilizer, and iron ore is found in very

many places, but no indications were observed of a deposit of this mineral, likely to prove valuable.

NATIVE FORESTS.

A section east and west through the center of the county, exhibits in an interesting manner the influence of the geological features upon the soil and its natural products. Commencing on the west line, the Berea grit marks the outline of the bluffs of Chagrin river. Between this and the base of the Conglomerate, the land is level; the soil a stiff, tenaceous clay, formed largely from the Cuyahoga shales, is, therefore, rich in potash; and the large elms scattered over this plateaux enable the explorer to trace this soil and this geological formation as far as the eye can reach.

Beech and maple forests, with thick groves of chestnut, where the broken rock comes near the surface, mark the horizon of the Conglomerate; and above this in the center of the county, a belt of forests in which the predominant timber is oak, defines with great accuracy the limit of the Coal-measures. Descending from this summit to the east, the same forest peculiarities are seen in an inverse order, so that the small patches of the old forests yet remaining, indicate to the experienced eye, with a good degree of accuracy, the geology of all parts of the county.

Many of the farmers of this region, express the opinion that the Conglomerate lands afford better pasturage than any other in the State, and that the dairy products obtained from them, are better, and have better keeping qualities than those obtained elsewhere. It is certain, that when this rock comes near to the surface, it produces the effect of thorough under-draining. The broken and porous character of the rock enables it to carry off with facility, during excessive rains, all surplus water, and yet to retain so large an amount of moisture, as to be of very special advantage during protracted droughts. I quickly learned while making exporations in mid-summer, that if a hill showed at a distance a deep green and closely cropped turf, the probabilities were very decided that the Conglomerate was there near the surface, and if in addition a clump of chestnuts were to be seen upon the hill, the presence of the Conglomerate was rendered quite certain. It was often a matter of surprise to note how thin a deposit of soil upon the Conglomerate would suffice for the support of good pasturage during the dryest part of the season. Another fact affecting the productiveness of this region should not be overlooked, and this is, that the annual rain-fall is here much in excess of the average of other parts of the state.

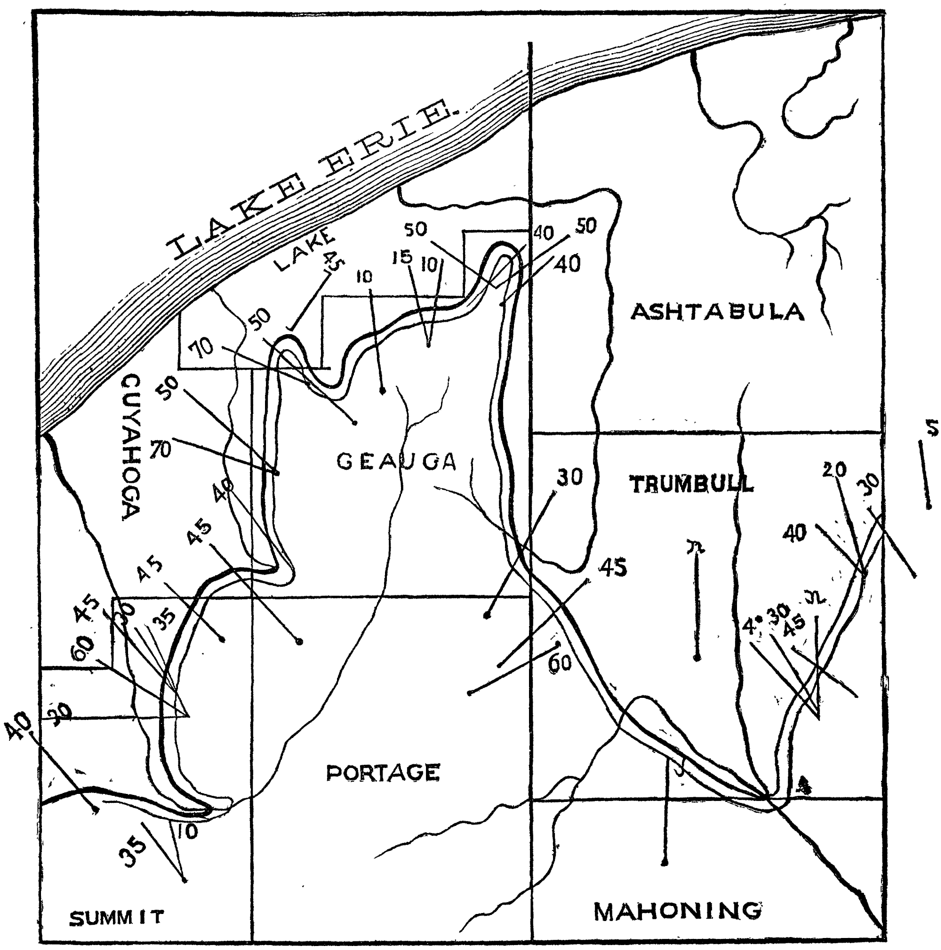
GLACIAL SCRATCHES.

The glacial markings are abundant in the county, and their direction has a close connection with the topography. The nature of this connection is best seen by observations extending over a wider area than the limits of the county. Commencing on the border of the Conglomerate, in Boston, Summit county, the direction of these glacial scratches varies from east and west to north-east and south-west, until, following the outcrop northwardly, their direction gradually approaches north and south; while, on the eastern margin, from Thompson southward, their direction is, in general, north-east and south-west. On the Cuyahoga shales, near Warren, Trumbull county, their direction is north and south, and on the elevated land near the east line of the state, in Hartford, Vernon, etc., their direction is again north-west and south-east. In many places there are several distinct systems of scratches with different bearings, but the most abundant take the directions indicated above.

These lines, radiating from near the center of the highest elevations, suggest the possibility of local glacial action, but the debris of the Conglomerate and of the rocks above it, is not found north of their outcrop, while that of all the rocks is constantly observed to the south, carried up and scattered over the formations occupying a higher geological and topographical level, so that fragments of the local rocks, mingled with the drift, observed in any place, are clear indications that the out-crop of these rocks is to the north. Had local glaciers been pushed down from both sides into the shallow valley between the eastern parts of Trumbull and Ashtabula counties, and the eastern margin of the conglomerate in Geauga and Portage, a series of north and south scratches would probably not be found along the center of this valley. The movement was doubtless in a southern direction, and the observed glacial markings would seem to indicate an ice sheet, of no great elevation, pushed southward with immense force, impinging against the more elevated rocks, pushing up and over opposing barriers, wearing down their margins, polishing their surfaces, and leaving scratches at various angles with the general direction of the ice movement.

A much slighter descent than is generally supposed would suffice to give a constant progressive motion to large fields of ice, and I am inclined to the opinion that the ordinary changes of temperature have more influence upon this progressive motion than is generally supposed. A broad sheet of metal upon an inclined surface will slowly creep downwards. Engineers have learned that if the abutments of an iron bridge

Map showing directions of glacial striæ along the margin of the highlands in Northeastern Ohio.



are not accurately level, the structure will move bodily down the slope, however small may be the angle of inclination. An increase of temperature elongates the structure, and if it rests upon an incline, however slight, this elongation will be wholly downwards. As the temperature decreases, the length of the structure is diminished, and from the action of gravity this contraction is also downwards, so that the structure slowly but surely creeps downwards precisely as a measuring worm or geometer moves over a surface. Such changes of temperature would insure a progressive motion of an ice field down a very slight slope, with a force and rapidity proportionate to its extent, and which would suffice to carry the margin up and over abrupt obstructions of an elevation even higher than any part of the ice field.

The map of that part of the Western Reserve east of Cleveland, on the opposite page, shows the direction of the principal glacial striæ of which the bearings were taken, the figures at the end of the short ruled lines indicating the degrees east and west of north, and the opposite ends of the lines the positions of the striæ.* These are not the only indications of glacial action in the county. The central parts of the whole table-land is ground down over large areas to a nearly level surface, which is smoothed and polished by ice action. The margin of the Conglomerate, except in a few places, is cut away, leaving a smooth rounded outcrop, such as would be caused by local glaciers pushing down the irregular gorges, or by a broad sheet of ice pushed upwards through these gorges on to the top of this table-land. It is near this outer margin where recent erosion has uncovered the rocks that the most of the observations of glacial striæ were made. At these places all the shaly sandstone which ordinarily caps the Conglomerate has been carried away, and the surface of the massive sandstone left smooth, rounded at the margin and polished.

GOLD.

The excitement from the alleged discovery of gold at Nelson ledges, has extended to Parkman and other places in this county, and if gold is actually found there, then there is no reason why search should not be made for it in every township of Geauga county. It is true that gold has been obtained from the drift in various parts of the state, and in some places at the margin of the Conglomerate, under such conditions as render it probable that it was derived from this rock. Indeed no metal except iron is more widely distributed than gold; but its great specific gravity renders it certain that it can never be carried in large

*The irregular double line upon the map marks the northern limit of the Conglomerate and of the high table land described in the text.

quantities by water, or other natural transporting agencies, to any great distances.

The quartz pebbles of our Conglomerate rock have doubtless their ancient home in the highlands of Canada, and gold bearing quartz veins may have furnished a small fraction of the materials from which these pebbles were derived; and if so, a small portion of these pebbles—one in ten thousand, or in one hundred thousand—may also be gold bearing. But as in these distant highlands no gold bearing quartz veins of sufficient richness to be profitably worked have yet been discovered, the search for these possible gold bearing quartz pebbles in the Conglomerate is not likely to prove a lucrative occupation.

At the base of the Conglomerate, at Nelson ledges, there are deposits of iron ore and of carbonaceous matter. Mingled with the pebbles, in close proximity to these deposits, are minute spangles and crystals of iron pyrites, such as have often been mistaken for gold, and probably often will be, although their extreme hardness, their crystalline surfaces, their changeable color when viewed at different angles, and the fumes of sulphur they will yield when heated, afford so many separate tests, by either of which they may be readily distinguished from gold.

After very careful search at the place of the alleged gold discoveries, I could find nothing visible to the eye, aided by an ordinary hand glass, which any one ought to mistake for gold. A specimen of the rock, selected as gold bearing by those who have faith in the alleged discoveries, has been carefully analyzed by Prof. Morley, of Western Reserve College, who was not able to find a trace of gold in it. The rich dairy lands of Portage and Geauga counties are doubtless the only gold fields accessible to the inhabitants, which can be worked with profit. In these they are to find their wealth, and not in the search for any of the precious metals. At the time the above was written, companies were organized for the alleged purpose of extracting gold from the pebbles of the Nelson Conglomerate. And pretended analyses of the rock were published, some of which showed a larger percentage of gold than can be obtained from the best quartz veins of California. It is understood now that the bubble has wholly exploded. But these attempts, whether prompted by ignorance or by avarice, to write up worthless territory as rich in valuable minerals, cannot be too severely censured. While mistakes will often be made, and money expended in the fruitless search for minerals within the limits of their possible occurrence, it is very desirable that there should be such a general diffusion of the elements of geological science as will prevent the possibility of such expenditures outside of such limits.

The following section illustrates the geological structure of the county, commencing with the upper member of the series:

No. 1. Sandstone.
No. 2. Coal shales.
No. 3. Coal No. 1, with a thin bed of shales in places below it.

These comprise the Coal-measure rocks of the county, and are designated on the map by a brown shading.

No. 4. The Conglomerate.
No. 5. The Cuyahoga shales.
No. 6. The Berea grit.
No. 7. The Bedford shales.
No. 8. The Cleveland or Black shale.

These constituting the Sub-carboniferous rocks—the Conglomerate shaded red, the others grouped together as the Waverly rocks and shaded yellow, a green line in the yellow marking the outcrop of the Berea grit.

No. 9, the Erie shales, the upper member of the Devonian, and the lowest rock found in the county, or in the eastern part of the state.

REPORTS

ON THE

SURFACE GEOLOGY OF THE MAUMEE VALLEY,

AND ON THE

GEOLOGY OF WILLIAMS, FULTON AND LUCAS COUNTIES, AND WEST SISTER ISLAND.

BY G. K. GILBERT.

TOLEDO, OHIO, April 15th, 1871.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—I have the honor to present herewith a report on the geology of Williams, Fulton and Lucas counties, and West Sister Island. The examination of Defiance county was in progress when my work in the field was interrupted, and a few days only will be necessary to complete it.

The absence of valuable minerals, and the great depth of the superficial deposits in this district, have rendered the detailed study of the indurated rocks at once unimportant and impracticable, and considerable attention has been given to the Drift, which is well displayed for examination. The three counties together afford a nearly complete panoramic view of its various phases in the Fourth District. For this reason, and because some of the conclusions attained are based in part on explorations carried beyond the county limits, I have devoted a separate chapter to the consideration of the generalities of the Surface Geology.

With great respect,

Very truly yours,

G. K. GILBERT.

CHAPTER XXI.

SURFACE GEOLOGY OF THE MAUMEE VALLEY.

The following description and discussion of glacial and post-glacial phenomena embodies the results of a detailed examination, made in 1870, of the country north of the Maumee river, together with the eastern division of Lucas county, and West Sister Island. Of the remainder of the fourth district, only a general reconnoisance has been made, but it has sufficed to indicate that the general character of the Drift continues unchanged as far south as Auglaize county, and it is believed that the conclusions here reached will apply to the major part of the fourth district.

The history recorded in the unconsolidated deposits of the region under consideration, admits of the following sub-divisions :

I. Glacial epoch.
- Glacier phase (striæ, moraines).
- Iceberg phase (Erie clay).

II. Post-glacial epoch (lacustrine clays and beaches ; *Mastodon giganteus*).
- First beach, *i. e.* upper beach.
- Second beach.
- Third beach.
- Fourth beach.
- Fifth, or present beach.

GLACIAL EPOCH.

The glacial theory for the origin of the Drift is now so widely accepted as to need no argument in this place, and I shall confine myself to a brief discussion of the particular phases of glacial action, to which this region has been subjected. But first, it will be necessary to describe the phenomena—striæ and detritus—in which this action is recorded.

GLACIAL MARKINGS.

The peculiar, planed and scored rock surface, that marks so unmistakably the passage of a glacier, is found, without exception, wherever

the Drift is freshly removed, and there is no reason to doubt that it exists throughout the entire district, save only in the few spots where it has been exposed to modern denuding agencies. Its preservation is perfect. The high polish and delicate striæ that have been wrought on the hard limestones, are as fresh as though produced but yesterday; while the softest beds, of which fresh exposures have been found, have proved equally retentive. The black shale of the Huron group, and the friable sandstone at the base of the Corniferous, both of which yield rapidly when exposed to the air, still bear the markings upon their clay-protected surface. The inference from this—that the deposition of the overlying clay must have immediately succeeded the retirement of the glacier—will be again referred to.

The bearing of the furrows, grooves and striæ, have been noted at numerous points, and, while local deviations dependent on details of topography are sometimes met with, the majority of the bearings are readily grouped in a single broad system of easy interpretation. Through the western portion of the trough occupied by Lake Erie, the ice moved nearly westward, bearing, however, a trifle to the south. Further west, in the broad Maumee valley—the prolongation of the same trough—it swerved still more to the south, moving west-southwest in Ottawa and Lucas counties, southwest in Defiance and Paulding, and south-southwest in Van Wert and Allen.

The more important bearings are given in the following table. Where a number of observations were made in the same neighborhood, the mean bearing only is given:

Locality.	Rock.	No. of obs.	Bearing.
South Bass Island	Limestone, Waterlime Gr.	Many.	S. 80° W.
Ditto (intersecting series)	" " "	1	S. 15° W.
Kelly's Island	" Corniferous "	4	S. 78° W.
Sandusky City, Erie county	" " "	2	S. 80° W.
Ballville, Sandusky county	" Waterlime Gr.	1	S. 65° W.
Genoa, Ottawa county	Limestone, Waterlime and Niagara Groups	2	S. 65° W.
West Sister Island	Limestone, Waterlime Gr.	Many.	S. 80° W.
Ditto (intersecting series)	" " "	1	S.
Sylvania, Lucas county	Limestone and sandstone, Corniferous Gr.	5	S. 50° W.
Monclova, "	Limestone, Waterlime Gr.	4	S. 62° W.
Fish's Quarry "	" Corniferous "	1	S. 55° W.
Whitehouse "	" " "	1	S. 50° W.
Near Defiance, Defiance county	Shale, Huron Gr.	1	S. W.
Near Junction, Paulding county	Limestone, Corniferous Gr	1	S. W.
Lima, Allen county	" Waterlime "	3	S. 35° W.
Middlepoint, Van Wert county	" " "	2	S. 15° W.

The striæ bearing south on West Sister Island are comparatively faint scratches on a surface already carved in deep furrows, having the prevailing direction, S. 80° W. As they occur at but one point, and are there parallel to a steep bluff over which the older grooves rise obliquely, it is presumable that they constitute merely a local feature and were formed by the retiring glacier, when its mass had become so reduced that it conformed in a greater degree to the inequalities of its bed. The shores of the island furnish good opportunity for the study of some features of the striæ. With slight exception, the shores are rock-bound, and afford frequent exposures of the glacier marks. Save at one point, whence a reef extends for some distance, the descent from the shore is very abrupt to a depth of thirty feet, where a clay bottom is reached. The highest point of the island rises over sixty feet above the water. When the ice traversed it, it constituted a knob on the bed of the glacier, scarcely three-fourths of a mile long and not less than one hundred feet high, over which the ice was forced. The amount of deflection to which this obstruction gave rise, is recorded in the scratches upon its sides. The east face, which breasted the ice current, bears grooves, S. 80° W. the general direction. The most divergent lines on the northeast face bear due west, and on the southeast face, S. 65° W., while on the entire remaining half of the shore, the "lee" side, there was no deflection. That is to say the ice went in a measure around, as well as over the hill, swerving, at the most, fifteen degrees from its course; but, after passing it, closed behind it from above rather than from the sides. There is every evidence that the pressure at the front was far greater than elsewhere. The rock is there planed to flat or convoluted surfaces, interspersed with long rectilinear furrows of great symmetry, while on the opposite shore the undulating surface of the rock has been merely scratched, and long, deep furrows are not seen. Had other evidence been wanting, we might have concluded from this inequality of wearing, that the glacier moved westward, and not eastward, at this point; but fortunately, an easier and more definite proof was afforded. The phenomena to which the resistance of the island as a whole gave rise, are beautifully reproduced in minature upon portions of its surface. Certain limestones belonging to the Waterlime group, and containing a great number of flint nodules of all sizes up to a diameter of two feet, bear the marks, on their outcrop, of the glacial friction. The hard nodules, of course, opposed far more effectual resistance to the grinding agencies than did the limestone, and, as the latter was planed away, they were left boldly prominent; and so they remain. On the "lee" side of each is a long, straight train or ridge of limestone that was protected by

it, and in turn served to buttress it. In front of each is a shallow groove, sunk below the general level of the limestone, and running in the form of a U around the front of the flint, while its ends are prolonged, parallel and adjacent to the trailing ridge. Both ridge and grooves fade gradually away into the general plain. The plastic condition of the glacier mass, on which depends the formation of the long grooves so characteristic of glaciated surface, is here strikingly illustrated. The ice (or since we are speaking of the base of the glacier, perhaps *frozen mud* or *frozen sand* would be more exact,) in front of the flint mass, being stopped in its progress, and hence subjected to increased pressure from behind, (in virtue of its properties as a solid,) distributed this pressure in all directions (a property of fluids). As an effect of the increased downward pressure the groove was worn at the base of the flint; by the increase in other directions a passage was forced above and at the sides of the obstruction. This being accomplished, the ice did not at once re-assume a plane surface, but, retaining the form given to it by the flint, carved it in turn upon the limestone. The tendency, here illustrated, of glacial ice to prolong a resisting knob into a ridge and a cavity into a groove, seems to afford a better explanation of the long, smooth, even furrows so frequently seen, than the theory that they have been engraved or plowed by large bowlders.

In the presence of these instructive nodules, there can be no question that the motion was towards the west. The same phenomena were observed on rock of the same age at Monclova, in Lucas county, where the motion was S. 60° W. Through the kindness of Mr. Coder and Mr. Wilson, of that place, a specimen slab was placed in the state collection.*

MORAINES.

The study of moraines is attended with considerable difficulty wherever the Erie clay has buried deeply the immediate glacier detritus. While this is the case throughout the northern part of the fourth district, I have nevertheless found such evidence as to lead to the belief that moraines occur there upon a scale commensurate with the magnitude of the accompanying phenomena. To understand the nature and value of this evidence, it will be necessary to look for a moment at the topography of the region in question.

The Maumee river occupies the axis of the broad, shallow valley which it helps to drain. This valley has no strongly marked limits. Eastward

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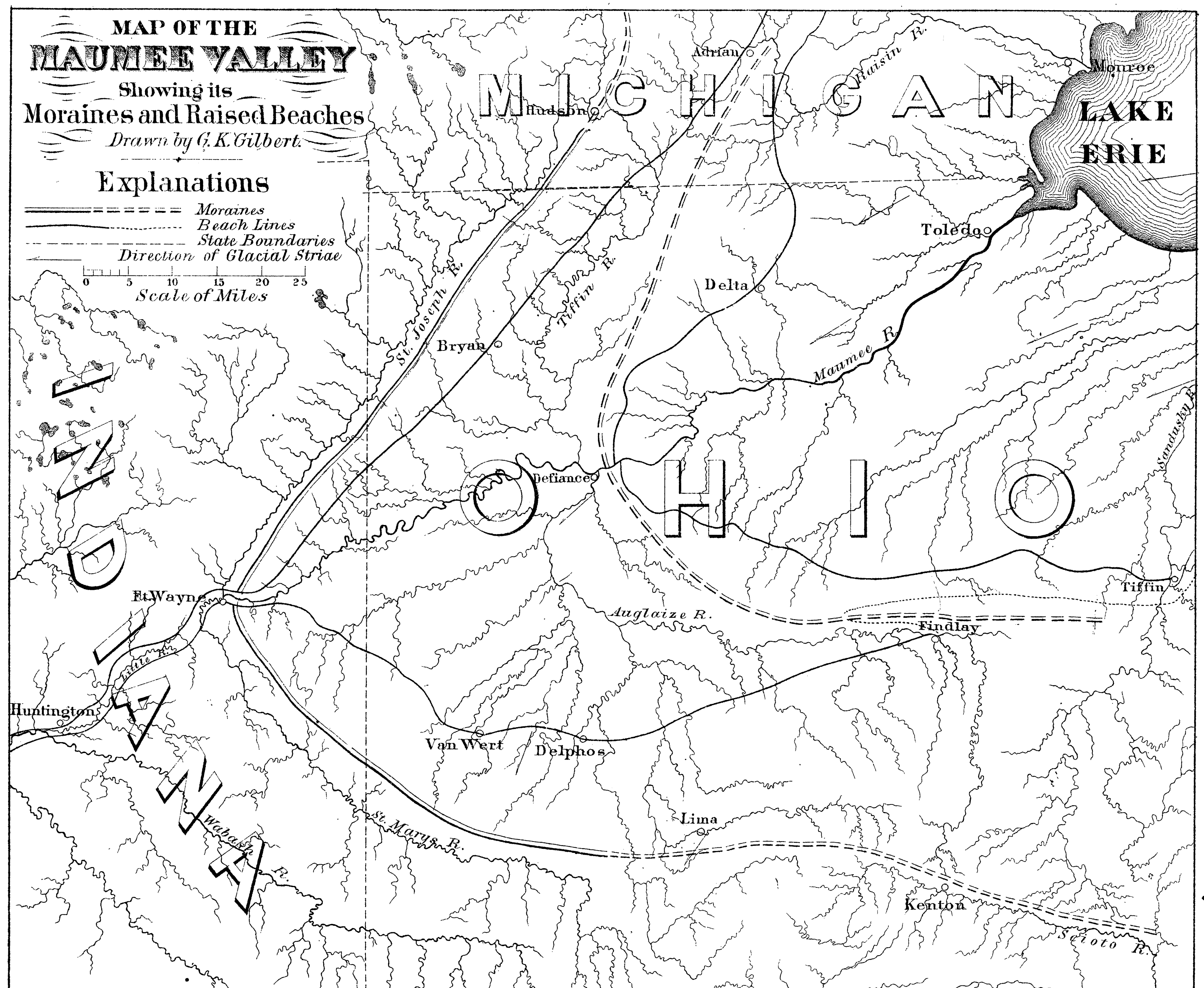
*Prof. James Hall has figured a somewhat similar slab, obtained from Corniferous limestone at Black Rock on the Niagara river, showing that there the direction of motion was S. 35° W.—*Nat. Hist. of N. Y., Geol. of 4th Dist., Pl. XIV.*



Strobridge & Co. Lith. Cin. O.

it is continuous with the trough of Lake Erie, and westward with the valley of the Wabash river. At the north, or more properly the north-west, its slopes merge, at a height of 500 to 600 feet (above Lake Erie), with those of the valley of Lake Michigan; and its southern slopes, reaching a height of 400 to 500 feet, pass into those of the Ohio valley. With these low sides and a width of one hundred and twenty-five miles, all its inclinations are exceedingly gentle, and the title of plain can be applied to it with no less propriety than that of valley. North of the Maumee the general descent is to the south-east, and south of that river, to the north-east. With slight exceptions, the smaller streams follow and indicate these slopes, but all the larger tributaries of the Maumee, including the St. Joseph, St. Mary's and Auglaize rivers, and Bean or Tiffin creek, appear to be independent of them. The St. Joseph, for example, flows to the south-west through a country where every rivulet runs to the south-east. The entire region drained by it lies on its right bank, while from its left the drainage is toward Bean creek, the divide between the two streams being everywhere within three or four miles of the St. Joseph. In like manner the course of the St. Mary's is west and north, and while from its left bank the streamlets flow north-east into it, from its right they flow north-east into the Auglaize. These hydrographical peculiarities, which may readily be noted on the accompanying map, are so singular and striking, as to have excited some attention and curiosity before the region was visited. Upon examination there was found a continuous ridge, following the eastern banks of these rivers, and evidently determining their courses. Running somewhat obliquely across the slopes of the country, it turned aside all the small streams, and united them to form the St. Joseph and St. Mary's. The height of this ridge is ordinarily from twenty-five to fifty feet, and its width at base from four to eight miles. Along the St. Joseph it is not distinguished from the adjacent country by its superficial characters. In common with that, it has a gently rolling surface, with a gravelly clay soil, supporting a heavy growth of varied timber. Further south, where it forms the north bank of the St. Mary's river in Van Wert and Mercer counties, it is marked by such peculiarities as to divide it very sharply from the adjoining plains, which are nearly level, with a soil of fine clay, and covered by a heavy growth of elm, beech, ash, maple, etc. The ridge, on the contrary, presents a confused series of conical hills, chiefly of clay, but showing some pebbles and small bowlders, and clothed by a forest growth almost exclusively of oak. Probably the only essential point in this contrast is that of hill and plain, and out of this the others have grown. There is good reason to believe that the clay deposit (Erie clay) of the plain is contin-

uous with that on the hills. Where its surface is level, it has retained its soluble salts and accumulated vegetable mold, so as to form a rich soil favorable to a varied vegetation; while from the steep hillsides a great amount of soluble and fine material has been washed, so as to bring to the surface some of the pebbles everywhere imbedded in greater or less abundance, and the character of the vegetation has been determined by that of the soil.

I conceive that this ridge is the superficial representation of a terminal glacial moraine, that rests directly on the rock-bed, and is covered by a heavy sheet of Erie clay, a subsequent aqueous and iceberg deposit. Though this formation has an average depth along the upper St. Joseph of over one hundred feet, and on the upper St. Mary's of fifty feet, it has not sufficed to conceal a moraine of such magnitude, but has so far conformed to its contour, as to leave it still visible on the face of the country—doubtless in comparatively faint relief, but still so bold as to exert a marked influence on the hydrography of the valley.

Of the internal constitution of this ridge, very little is known. At Fort Wayne, Indiana, where it is traversed by the Maumee, no fresh section is afforded, and nothing is shown save the absence of a rocky nucleus. Between Kossuth and Spencer, where it is crossed by the Miami canal, a cut of 36 feet was made, but nothing exhibited further than the ordinary Erie clay. The idea that it contains a ridge of undisturbed rock is entirely inadmissible, as it crosses at various angles outcrops of the Waverly, Huron, Hamilton, Corniferous and Waterlime groups.

From a point near Hudson, Michigan, it has been traced along the east banks of the St. Joseph and St. Mary's rivers, to Fort Amanda, Auglaize county, a distance of 120 miles. In this space it is interrupted only by a notch at its lowest point, where the Maumee passes through. Beyond the extreme points indicated, it has not been followed, but an inspection of the map suggests that it may be found in Michigan, retaining the upper waters of Bean creek, and in Hardin county, Ohio, sustaining a like relation to the Scioto. On the accompanying chart, it has been indicated by a double line—full where its position has been ascertained, and dotted where it is merely surmised. Together they represent a curve 200 miles in length, with a chord of 120 miles.

The courses of Bean creek and the Auglaize river are defined by a similar ridge, but less symmetrical in its form, and, as it falls within the circle of the ancient lake beaches, so greatly modified by lacustrine erosion as to retain none of the superficial characteristics, by which the other is in part distinguished. It bears, however, such resemblance in

form and position, that it may, with propriety, be referred to the same causes.

By reference to the Map of Raised Beaches, it will be seen: 1st, that these ridges are approximately parallel or concentric; 2d, that they are rudely crescentiform in outline, presenting their convexities toward the south-west; and 3d, that the course of the glacial ice in the Maumee valley—indicated by arrows—was to the south-west. All these features accord with the idea that the ridges are due to successive terminal moraines of the glacier that moved up the valley; or, more strictly, in a direction which is now up the valley. Adopting this view, we are here furnished partial outlines of the great ice-field, at two stages of its recession. Though but small fractions of the entire outlines, they yet suffice to indicate that the margin was lobed or digitate in conformity with the topography of the country it traversed.

Whether earlier stages of the glacier, when its borders were carried further south, have been recorded by similar, continuous moraines, I am not prepared to say, as I have not traversed the region where they should be sought since my attention has been called to the subject; but the result of a single observation, made last autumn, is so significant that I will give it place here, though it is at present quite isolated. At the village of St. John's, Auglaize county, is a hill, quite distinct in character from the surrounding country, which presents a rolling surface of clay with scattered bowlders—apparently the Erie clay. The hill in question is abrupt and conical* in form, and rises about fifty feet above its visible base. It is composed of slightly worn, limestone gravel, unsorted, but free from clay and fine sand, and derived from the Waterlime group. To this group belongs also, without question, the subjacent rock, though the immediate vicinity affords no exposures. The pebbles have lost, by attrition, only their acute edges, and distinctly preserve the cuboid forms into which that stone is prone to break. In this they differ widely from the pebbles of the Erie clay, which are generally thoroughly worn. A few glaciated surfaces were seen, but they are not common. Mingled with the mass, are small Eozoic bowlders, but so sparsely that they were found only after search; and it is not improbable that limestone of a different age escaped notice. Still, we may safely say that over ninety per cent. of the whole is derived from the rock which underlies, and which stretches in an unbroken sheet for fifty miles to the north

* The term *conical*, for want of a better, has been somewhat violently pressed into service, to describe the steep-sided, and apparently heaped-up, hills of irregular outline, that so characterize the drift in many localties, and is here used in that restricted sense.

and north-east. Some depressions of the surface of the gravel are occupied by thin beds of reddish clay, containing rounded northern bowlders.

I am informed by persons resident in the vicinity, that such hills occur at numerous points in the county; and, until more extended exploration has been made, any attempt to fully explain their origin would be premature; but I think that, with the data at hand, we may safely conclude that the hill at St. John's is older than the surrounding Erie clay, and that it is a moraine of some sort.

ERIE CLAY.

This deep and important deposit is composed of clay, sand, gravel and bowlders. In the country north of the Maumee river, its most constant characteristic is its variability, all its components displaying great unevenness of character and distribution.

The clay, which forms the chief mass, and serves, in great part, as a matrix for the other materials, is finely laminated, and, while often impalpable, is more commonly, in some degree, charged with sand. Its color is generally a neutral, brownish blue, but a lighter and more positive blue is often seen, and some exceptional and limited strata have been described as nearly white. These colors maintain in all the deeper portions, but at the surface, and thence to a depth of from two to twenty feet, the color has been changed to a dull yellow or buff. The line of demarkation between the two is the limit of the percolation of surface water, and is often marked along the banks of streams by springs, and there can be little doubt that the aerated water, which has thus traversed the upper portion, has changed its color by the oxidation of its iron.

Sand and gravel are mingled with the clay in all proportions, and are also interstratified in distinct beds. These beds are often of considerable depth, but are of limited area, so that they can be traced for but short distances. They are, however, very numerous, especially in Williams county, and in many localities are so connected as to convey water. To tap these water-bearing beds a great many wells have been bored, and in this way complete or partial sections of the deposit have been obtained at numerous points. In most cases the auger passes through a variety of beds—pure clay, sandy or gravelly clay, sand, gravel, "hard pan," (this term is locally applied by the well-borers to a firm, dry mixture of sand and gravel with enough clay barely to fill the interstices,) &c.,—but they occur in no uniform order, and wells only a few rods apart often traverse very different series of materials.

Bowlders are found at all depths, and of all sizes up to a diameter of twenty feet. Of the larger a majority show one or more glaciated faces,

faces, that is to say, flattened, polished and marked with parallel, straight scratches.

The surface of the deposit has been, in chief part, remodeled by the Lake water that at one time covered half the Maumee valley, but the higher land remains undisturbed. The line of the upper beach [See Map of Raised Beaches] marks off, in the north-west corner of the state, a triangular area—including two-thirds of Williams county, with portions of Defiance and Fulton—occupied by unmodified Erie clay. From the beach, which has an altitude of 220 feet, to the north-west angle, there is a total ascent of 200 feet, of which the greater part is west of the St. Joseph river. The surface is undulating or rolling, the swells rising ten to thirty feet above the swales. In general the slopes are gentle, but in places, and especially on the higher lands, they are somewhat abrupt. The greater part of the steep declivities are due, however, to the erosion of streams. Depressions without outlets abound and constitute a characteristic feature. A small number of them contain lakelets, but the majority have been so far filled with marl and peat as to become converted into swamps. All varieties of the deposit are exhibited in the soil, which defies classification. The phrase gravelly clay would apply to most of it, but nearly every farm shows some unmixed clay, and in the town of Northwest, Williams county, is a tract of clean yellow sand. Large bowlders are most abundant on the higher land.

The average depth of the deposit in the tract north of the Maumee river is not far from one hundred feet. In its original distribution, it probably lay as deep upon the hills as in the hollows, but within the circle of Lake action it has been so far leveled that its present surface is in great measure independent of the form of the underlying rock. This is especially the case near the present Lake, where the leveling forces have been longest at work, and at a few points on the limestone ridge, in western Lucas county, the drift has been entirely removed. The depth of the drift has been obtained at numerous points, and a large number of notes were taken in regard to it. While the present utility of these is not apparent, they may, at some time, be of value, and I have accordingly selected, in the following table, such as seem most worthy of preservation. Where the star (*) is affixed to the depth, it indicates that the rock was not reached; but, as the explorations generally ceased when water was found, and as water is very commonly obtained from a gravel bed resting directly on the rock, it is presumable that most of the borings given terminated near the base of the drift. At West Jefferson, Metamora and Phillips' Corners, however, the work was abandoned without obtaining water.

Depth of Drift in Williams, Fulton and Lucas counties.

Williams Centre	Williams county	110*	feet.
Bryan	" (135 ?)	109*	"
West Jefferson	"	80*	"
Stryker	"	127	"
Lockport	"	112*	"
Archbald	Fulton county	146	"
Wauseon	"	166*	"
Delta	"	85	"
Phillips' Corners	"	150*	"
Metamora	"	145*	"
Fulton township	"	80	"
Richfield	Lucas county	65	"
Tremainsville	"	89	"
Toledo,	"	100	"
Oregon, 3 miles east of Toledo...	"	80	"

Since in its origin the Erie clay is a mass of glacial detritus, distributed by water and icebergs, the examination of its components should tell something of the direction of the currents of ice and water by which they have been conveyed. A collection of bowlders, made at Toledo, at the foot of a bluff exhibiting thirty feet at the top of the deposit, comprises the following rocks:

	No. of specimens.	
Limestone of Hamilton group	2	
" (and 1 flint) of Corniferous group	10	
" of Waterlime group	3	
" Hudson river group	3	
" Trenton group	10	
" not identified	11	
Black shale of Huron group?	4	
Sandstone (red, white and gray)	14	
Silicious conglomerate	4	
Non-metamorphic		61
Chlorite schist	1	
Quartzite (white, gray and flesh-colored)	10	
Gneiss (gray to pink; less mica than hornblende)	26	
Greenstone	9	
Metamorphic and intruded		46
Total		107

In a handful of fine gravel, obtained in well-boring from near the bottom of the clay, at Toledo, were found:

Limestone pebbles	104	
Black shale	5	
Sandstone and flint	5	
		114
Metamorphic		29
Total		143

A series of small pebbles from the surface of the unmodified Erie clay, near Edgerton, Williams county, comprises:

Chert	24	
Limestone*	19	
Non-metamorphic		43
Quartzite	22	
Gneissoid	90	
Metamorphic		112
Total		155

In each case, care was taken to avoid the unconscious selection of conspicuous specimens, and to make the collections fair representatives of the beds from which they were derived. Reducing them to percentages for comparison, we have:

	Per cent. non-metamorphic.	Per cent. metamorphic.
Edgerton, top of Erie clay	28	72
Toledo, upper 30 feet of Erie clay	57	43
Toledo, near base of Erie clay	80	20

These figures give numerical expression to a fact that has been confirmed by the inspection of the surface over large areas, and of the lower portions at many points—the fact that the Laurentian rocks predominate over the ordinary sedimentary in the upper portions, while the reverse is true in the lower, and the intermediate parts present a gradation. When a gravel bed occurs at the base of the deposit, it is usually, though not invariably, made up entirely of fragments, little worn, of the rock on which it rests.

Having now presented the principal facts that my examinations have elicited, it remains to consider the history to which they pertain. I

* These pebbles presented only silicious skeletons, all the soluble portions having been dissolved away; perhaps some had in this way entirely disappeared.

conceive that the sequence of events in the Maumee valley has been somewhat as follows:

The ice sheet that at one time covered the entire district, not only removed all antecedent superficial materials, but changed the details at least of the rock surface, and left its own track as the convenient and inevitable starting point for the study of the drift changes. As the limits of the glacier were contracted, by whatever cause, its lower margin occupied successively every portion of its former bed, depositing upon it such material as the glacier plowed up and transported. During some portion of this recession, the margin was washed by a deep body of quiet water,* which floated off sections of the glacier, with its heterogeneous detritus frozen in them, and at the same time carried in suspension some of the finest ground material. It thus assumed the distribution of the whole material, save such coarse fragments as, being freshly torn up, had not yet become imbedded in the ice. Where this was the case, the deposition of the iceberg drift (Erie clay) commenced immediately after the retirement of the glacier, and either directly on the glaciated rock surface, or on a thin ground moraine of material but little removed from its parent bed. These conditions maintained, as I believe, while the ice front was retreating across the Maumee country. When the accumulation of the Erie clay began there, the icebergs that dropped it were broken from the adjacent margin of an ice field that bore *souvenirs* of a journey across many miles of limestones and shales, as well as other miles of gneiss and quartzite. As it continued, the margin gradually receded northward, until, when the currents ceased to float the icebegs thither, the parent glacier had become nearly restricted to the area of metamorphic rocks.

When from a temporary or partial suspension of the causes which contracted the ice mass, it was permitted for a time to reoccupy areas once deserted, whatever iceberg drift had accumulated there was pushed

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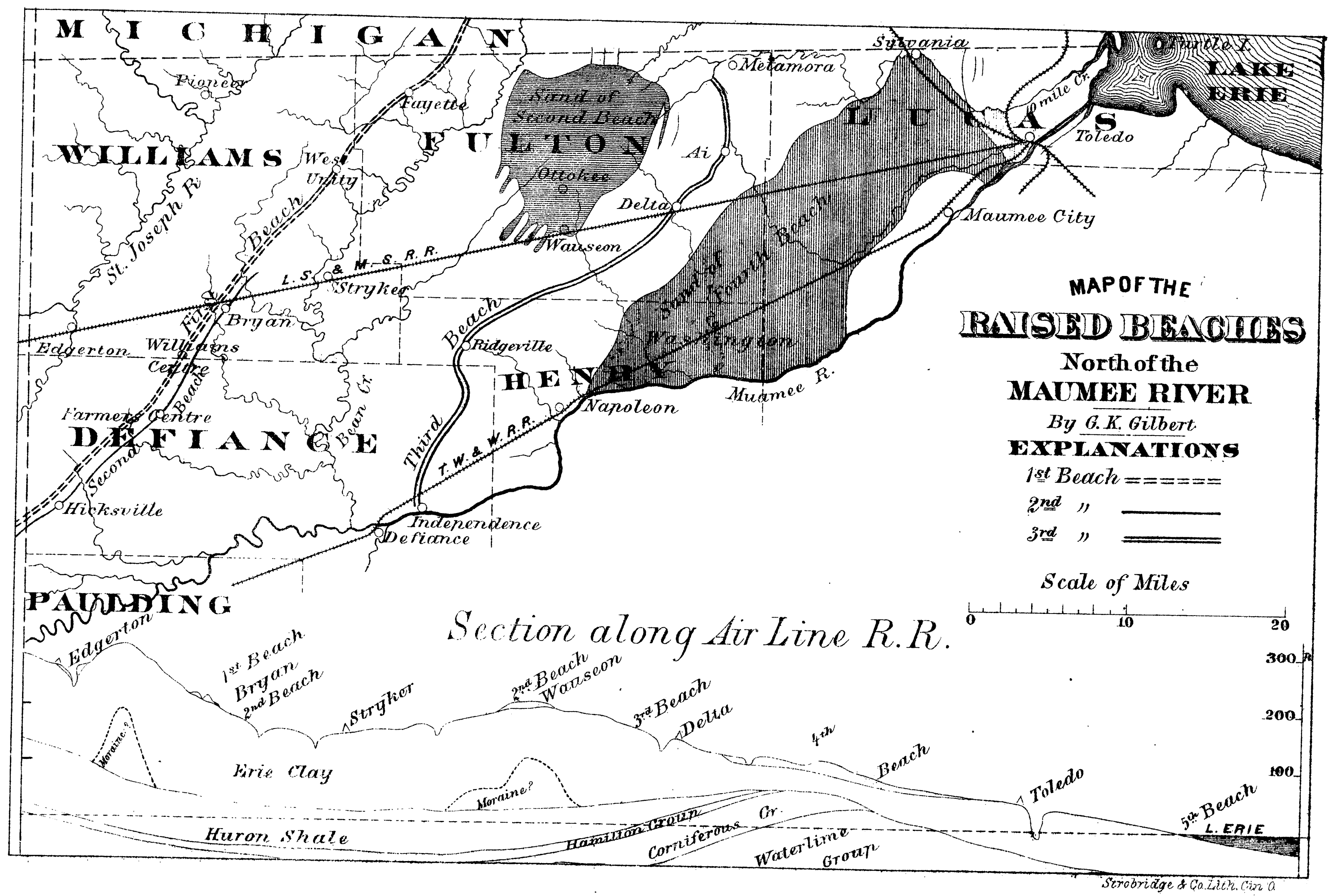
*The rise of the ocean, if accompanied by no climatal change, may have directly caused the diminution of the icefield; for whatever portion of it became so submerged as to be supported by the water, would be broken off and floated away. That such an explanation is not of general application, seems proved, however, by the subaerial deposits, (peat, &c.,) that intervene in southern Ohio, between two beds of glacio-aqueous origin.

It is noteworthy that no proof has yet been found in north-western Ohio of this interval in the progress of glacial phenomena. The negative evidence afforded by several hundred wells, though liable to be overthrown by a single affirmative fact, must still be allowed considerable weight, and warrants the suggestion that northern Ohio may still have retained its ice-cloak, while the Ohio valley was covered, for a time, by vegetable and animal life.



MAP OF THE
RAISED BEACHES
North of the
MAUMEE RIVER
By G. K. Gilbert
EXPLANATIONS
1st Beach
2nd "
3rd "
Scale of Miles
0
10
20
MICHIGAN
WILLIAMS
FULTON
LUCAS
HENRY
DEFIANCE
PAULDING
LAKE ERIE
Turtle I.
Toledo
Maumee City
Sylvania
Metamora
Sand of Second Beach
Sand of Fourth Beach
Ottokee
Wauseon
Delta
Ai
Fayette
West Unity
Pioneer
St. Joseph R.
Bryan
Stryker
L. S. & M. S. R. R.
Edgerton
Williams Centre
Farmers Centre
Hicksville
Second Beach
Beach
Third Beach
Ridgeville
Washington
Napoleon
Maumee R.
T. W. & W. R. R.
Independence
Defiance
Bean Cr.
Section along Air Line R. R.
300 ft
200
100
1st Beach
Bryan
2nd Beach
Stryker
2nd Beach
Wauseon
3rd Beach
Delta
4th Beach
Toledo
5th Beach
L. ERIE
Erie Clay
Moraine?
Huron Shale
Hamilton Group
Corniferous Gr.
Waterlime Group
Strobridge & Co. Lith. Cin. O.

forward to form a terminal moraine, and this was afterwards covered, in common with the adjacent land, by other detritus of the same character.

POST-GLACIAL EPOCH.

On the final removal of the sea or ocean beneath which the Erie clay was deposited, a body of water still remained in the great Lake basins. However that removal was effected, considerable vertical movements of the land must have been involved, and these did not cease with that event, but have continued, either at intervals or perpetually, to the present time. Their effect on the Lake basin has been to so elevate and depress its rim at various points, that, not only has the elevation of the outlet been frequently changed, but it has even been transferred from point to point of the low rim. In some cases these changes have been effected very slowly, and in others with comparative rapidity. In the intervals of repose, the waves have marked beach lines on the shores at the successive water stages, some of which have been above and others below the present levels of the various lakes. How many of these beaches have been formed cannot certainly be announced, for such as have been subsequently submerged must, in most cases, have been obliterated by the leveling action to which soft materials are subjected in shallow water. The beaches that are preserved on any shore represent a descending series of maxima of water level on that shore,—just as the storm lines of a coast do not mark all the storms that have raged against it, but only a limited series, of which each was more powerful than any that have succeeded it. Hence, in speaking of the beaches in order as the "first," "second," &c., I would not be understood to assert that no beach may have been formed before the upper, or that the others represent an uninterrupted temporal succession.

The Maumee valley is well adapted to the display of these beaches, since on its easy slopes they are so broadly separated that they can be traced without confusion, and in its soft drift they were inevitably modeled at every stage of the water's lingering. Four shore lines above the present are distinguished. The first marks a water level at 220 feet, the second at 195 feet, and the third at 170 feet above the Lake, while the fourth records a slow descent from 90 feet to 65 or 60.

West and north of the first beach—that is, above it—the Erie clay lies undisturbed, with the rolling surface it received from the unequal heaping of the iceberg loads of which it is largely composed. Upon such a surface the results of shore action could not escape notice, and the evidence of its absence is not merely negative in its character. I feel warranted in saying that from the north-west corner of the state to the

upper beach, (a horizontal distance of twenty miles with a fall of 200 feet), the waters of the glacial sea did not linger in their descent.

The Upper Beach consists in this region of a single bold ridge of sand, pursuing a remarkably straight course in a north-east and south-west direction, and crossing portions of Defiance, Williams and Fulton counties. It passes just west of Hicksville and Bryan; while Williams Centre, West Unity and Fayette are built upon it. When Lake Erie stood at this level it was merged at the north with Lake Huron. Its south-west shore crossed Hancock, Putnam, Allen and Van Wert counties, and stretched north-west, in Indiana, nearly to Fort Wayne. The north-western shore line, leaving Ohio near the south line of Defiance county, is likewise continued in Indiana, and the two converge at New Haven, six miles east of Fort Wayne. They do not, however, unite, but, instead, become parallel, and are continued as the sides of a broad water-course, through which the great Lake basin then discharged its surplus waters south-westward into the valley of the Wabash river, and thence to the Mississippi. At New Haven this channel is not less than a mile and a half broad, and has an average depth of twenty feet, with sides and bottom of drift. For twenty-five miles this character continues and there is no notable fall. Three miles above Huntington, Ind., however, the drift bottom is replaced by a floor of Niagara limestone, and the descent westward becomes comparatively quite rapid. At Huntington the valley is walled, on one side at least, by rock *in situ*. In the eastern portion of this ancient river-bed, the Maumee and its branches have cut channels fifteen to twenty-five feet deep, without meeting the underlying limestone. Most of the interval from Fort Wayne to Huntington is occupied by a marsh, over which meanders the Little river, an insignificant stream, whose only claim to the title of river seems to lie in the magnitude of the deserted channel of which it is sole occupant. At Huntington, the Wabash emerges from a narrow cleft of its own carving, and takes possession of the broad trough to which it was once but a humble tributary. The limestone above Huntington is the rocky rim or dam which determined the altitute of the overflow at this point, and is 170 feet above the present level of Lake Erie. Above it, the stream must have resembled the Detroit, bearing a smooth surface, but with enough current to excavate its soft bottom somewhat deeply where the marsh and prairie of the Little river are now spread; below, it was more comparable to the Niagara at Buffalo, where it rushes over the outcrop of the Corniferous limestone. At Fort Wayne, the St. Joseph and St. Mary's contributed their waters. Their mouths were fifty feet higher than now, and the flood-plains of gravel and sand which they then formed, now flank their valleys as ter-

races, and can be traced for forty miles toward their sources. When they were united by the retiring of the Lake, but slight cause was needed to turn them eastward along the level bottom of the deserted channel, and they have now cut their beds so deeply in the drift, that the highest freshets do not connect them with the Little river.

In addition to its general interest, the fact of this ancient south-westerly lake-discharge is an important element in the study of the nature of the changes, in virtue of which the lakes have stood at so many different levels since the ice period. The water which formed these beaches, and *discharged* through this channel, could not have been an arm of the ocean, but must have been contained by a solid barrier. To restore these conditions now, we would need not merely to fill the gorge at Niagara, and renew the escarpment at Lewiston, but to construct on that escarpment a retaining wall 170 feet high and many miles in length; and the task of preventing an outflow by way of Lake Michigan and the Illinois river would be no less stupendous. The conclusion cannot be avoided that the Wabash outlet is now, in its relation to the other parts of the great rim, not less than 170 feet higher than it then was.

The more general conclusion that the system of raised beaches signify a succession of flexures of the earth's surface, rather than the successive stages of subsidence due to the gradual removal of a barrier of tide water, or the gradual wear of a barrier of stone,* does not rest on this single fact. The waters of Lake Michigan have at one time found outlet, through the Desplaines and Illinois valleys, to the Mississippi, and Prof. A. Winchell reports a long-deserted channel through which Lake Superior has discharged directly into Lake Michigan.† The highest beach at the head of Lake Michigan has an elevation of but 65 feet above the level of Lake Erie, while Prof. Winchell mentions a water line on Mackinac Island 200 feet higher; and there is everywhere such discrepancy between the series of beaches at widely separated localities that their identification cannot be determined from a simple comparison of altitudes. There is

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*Prof. L. Agassiz refers beach-marked changes of level on Lake Superior to upheavals in connection with dykes. (L. Sup., its Physical Character, &c., 1850, p. 415.)

Dr. J. S. Newberry says: "We can readily imagine that local changes of level in the land have not only greatly affected the breadth of water surface in the lake basin, but have perhaps in some instances produced what we have supposed to be proofs of great and general elevations of the water level, which are, in fact, only indications of a local rise of the land." (Proc. Bost. Soc. Nat. Hist., Vol. IX.)

Compare also the remarks of Prof. E. Andrews, of Chicago, in the Transactions of the Chicago Academy of Sciences, Vol. II., pp. 13–14.

†Troy meeting of the American Association, 1870, as reported in the American Naturalist, Vol. IV., p. 505.

evidence that Lake Ontario, at Rochester, N. Y., has stood seventy feet lower than it does now. A submerged, vertical cliff of corniferous limestone that Prof. Winchell saw near Thunder Bay Island,* suggests that a former beach of upper Lake Huron may there lie ninety feet under water. Some features—to be described below—of the coast of Lake Erie, near Toledo, seem to warrant the conjecture that the last movement of the water there was an advance. And, finally, Mr. G. R. Stuntz has been led, by facts that appear entirely adequate, to the conclusion that the shores of Lake Superior are either sinking at its upper end, or rising at the lower, so that its beach lines are now being carried further west.†

While these facts abundantly prove that a simple theory of gradual drainage, by the elevation *en masse* of the lake regions, is entirely inadequate, they are too fragmentary to define clearly the general synchronism and sequence of the local movements to which they testify. Nevertheless, it is something to have learned that the writhing of the surface of our earth, which has in the ages so many times remapped the continents, has also been the great immediate cause of the transformations of the great lakes, and that, continuing through the latest distinguishable geological epoch, and its prolongation the historical, it has not now ceased. We may read once more in this the lesson, which modern science teaches in so many ways, that the present is but the continuation of the past; that geology, as well as history, is now enacting; and that it is only because of the brevity of the time allowed us for comparison that nature seems to have reached or approximated an equilibrium.‡

The Second Beach lies but twenty-five feet lower than the first, and runs parallel to it across Defiance county, and a portion of Williams. In the neighborhood of Hicksville and Farmers' Centre, which are located upon it, it consists of a single sand ridge, resembling the upper in size and character. Further north it diminishes in height, and gradually changes to a low step on the plain with no accumulation of sand, and is not easily traced far beyond Bryan. Its disappearance is due to the protection which this part of the coast received from a peninsula stretching southward from Michigan and occupying the central part of

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* Rept. on Geol. of Michigan, 1860, p. 62.

† Recent Geol. Changes in N. W. Wisconsin, Proc. Am. Ass., 1869, p. 205.

‡ In the discussion of these facts cited by Mr. Gilbert, and others of similar character, it should be remembered that the retreating glacier must have, for ages, constituted an ice dam that obstructed the natural lines of drainage, and may have maintained a high surface level in the water-basin which succeeded it. This subject will be referred to again in the general discussion of the Drift, which will form part of another volume.

J. S N.

Fulton county. When the water first arrived at this stage, it is probable that this area presented a broad shoal, over which beach sand was accumulated. As successive portions were brought to the surface of the water, the lighter sand was caught by the wind and tossed into dunes precisely similar to those whose formation can be watched on modern beaches. Prof. Andrews, of Chicago, in a valuable paper, to which I have already had occasion to refer, describes the sand accumulations of Lake Michigan, modern and ancient, and develops the conditions of their production essentially as follows: "It is a function of waves breaking against a shore to roll, and slightly lift sand and other materials too heavy to be taken into suspension. When they co-operate with a current, sand is transferred by them along the shore, but this transfer takes place only within the limited depth at which the wave-force can lift sand. Where a current, having followed the shore, turns from it, the sand cannot follow, and an accumulation is the result. On the other hand, where a current sets toward the shore, and, dividing, passes to the right and left, it carries off material, but brings none, and the shore is, in consequence, eaten away by the waves." These are but special cases of the general law that wherever the shore current is accelerated the waves cut away whatever oppose them, and wherever it is retarded they accumulate sand. It is only at points of accumulation—where the land is encroaching upon the water—that dunes occur. No one who has approached Chicago by rail from the east, can have failed to notice, at the head of Lake Michigan, the tract of drifting sand, rising in successive billowy swells, with interspersed ponds and lagoons, and with a straggling growth of oak and pine. This tract is the immediate creation of the waves, currents and winds, and is constantly extending its limits lakeward. The sand hills of the "oak openings" district, in Fulton county, originated in the same manner, from sand moving southward along the old coast. Its lagoons have been filled with sand and vegetable mold and converted into marshes and prairies. Its hills have become somewhat more rounded in outline, and their sand yields to the wind only at the most exposed points; but their arboreal vegetation is still exclusively of oak, and it is only upon the flatter portions that these can be said to flourish.

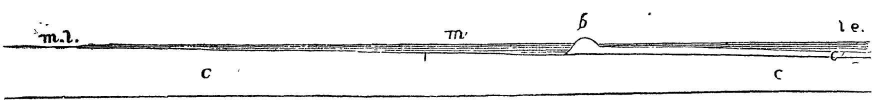
The sands which form the several beach ridges have been derived immediately from the sorting of the heterogeneous drift. The finer material was deposited in deeper water, forming what may properly be called *Lacustrine clays.* These beds are nearly level and quite free from gravel, and generally constitute the surface of the country between the beaches. Between the second and third, however, some of the higher points of the gravelly Erie clay were not covered by them.

The Third Beach, like the first, is marked only by a simple ridge of sand, or, in places, of fine gravel. Crossing the Michigan boundary near the east line of Fulton county, it takes, at first, a southerly course, but soon curves so far to the west as to reach the south line somewhat west of the middle. Continuing its south-westerly course across a portion of Henry county, it again turns south in Defiance, and reaches the Maumee at Independence, four miles below Defiance. At this point it was formed on the summit of a ridge of Erie clay, to which I have already referred as a glacial moraine, and west of it a land-locked bay stretched up the Maumee valley.

What I have designated the Fourth shore-line is a broad belt of sand, covering the slope from an altitude of 90 feet down to one of 60 feet, or even lower. It is chiefly in the form of dunes, covered by "oak openings," but along the lower margin the sand is leveled, and merges gradually with the lacustrine clay, which stretches in an unbroken sheet to the present Lake. It seems probable that this accumulation took place during a gradual subsidence of the water from 90 to 65 or 60 feet. The boundaries of this belt are by no means so definite as they have to be represented in mapping, but the limits that I have traced [See Map of Raised Beaches] will not far misrepresent its area in Lucas and Fulton counties.

The existing shore of the Lake is guarded, within the limits of Lucas county, by a simple ridge of sand. The underlying clay slopes lakeward at a nearly uniform rate of five feet per mile. Upon this the sand ridge rests at a distance of from one to one and a half miles from the main shore, so that its base is six or eight feet below the water level.

FIG. A.—*Showing the relation of the protective beach to the shore of Lake Erie in Oregon, Lucas Co. (Vertical scale 20 times the horizontal.)*



In fig. A, *c* represents the ancient lacustrine clay; *c'*, the clay or mud now depositing; *l. e.*, the water of Lake Erie; *b*, the sand beach; *m*, the marsh or lagoon that stretches to the mainland, *m. l.* The top of the ridge averages but three or four feet above the water, and at numerous points fails to reach the surface at all. From its western extremity, Cedar Point, a bar appears to be extending slowly toward Turtle island. The water is now shallower on that line than within Maumee bay, and it is not improbable that Turtle island is the remnant of a previous high

bar, though men who have been familiar with the coast for twenty years report no change.

It is noteworthy that the small streams which enter Maumee bay occupy, near their mouths, larger channels than it seems natural that they should have opened under the existing conditions. One of them was examined in detail, with measurements, and may serve as an example.

Ten Mile creek (Ottawa river of some maps,) drains a strip of flat country thirty miles long, and with an average width of six miles. Of the lower half of its course the bed is entirely of drift clay, as are its banks everywhere. Slack-water begins seven miles from the mouth, near Tremainsville. A half mile from the mouth it presents a water surface of sixty rods. The main channel is central, with a medial depth of fifteen feet, and a width of four rods. Its margins are about seven feet under water, and from them up to the banks the slope is gradual. The change at present, in progress here, seems to be that the waves are cutting into the low clay banks, and, with the removed material, contracting the margins of the channel. The upper half of the slack-water valley is occupied by a marsh continuous with the bottom land above, through which the water channel is but twenty feet broad and six deep. There is every appearance that this marsh is encroaching on the open water, and that the channel below, being larger than the creek requires, is being filled with its sediment.

If we suppose that the present water level of the upper end of Lake Erie was immediately preceded by a lower level, we have an easy explanation of these phenomena, for with lower outlets the streams would readily excavate the channels they are now engaged in filling. The same hypothesis may help to solve another problem. It is shown in Prof. Hall's report on the geology of New York, that the crest of the ridge through which the Niagara has cut its gorge, is thirty-eight feet above Lake Erie. The fall of the water line through these thirty-eight feet was necessarily very slow—so slow that it cannot have failed to record in beach lines its progress. But in Lucas county no beach lines can be traced within this vertical distance, and on West Sister island the perfect preservation of glacial striæ on exposed coasts at all heights up to thirty feet, afford positive evidence that the line of beach action has not slowly traversed them. So we must look for the record of this work considerably above, or somewhat below the present coast, though present data do not indicate which is the more probable position.

The only fossil remains that I have to report from the superficial deposits are of mastodon, and all post-glacial. The deep swamps of

north-western Williams county, which have been slowly accumulating marl and peat ever since the close of the ice period, cannot fail, when these deposits are dug into, to yield many specimens. None have been found there as yet, but a few bones were exhumed some years since in an adjoining county of Indiana, from a swamp of the same system. In the past summer (1870) a partial skeleton was obtained from a swamp of the same antiquity in Auglaize county. It was discovered in Clay township, two and a half miles east of the village of St. Johns, by farmers engaged in running a broad ditch through the swamp. The depth of the swamp at that point is eight feet, of which the upper third is of peat, and the remainder, so far as shown, of marl or marly clay. The bones were found in natural juxtaposition, and in such shape as to leave no question that the animal was mired and died in the place where he was found. The doubts that have recently been expressed as to the post-glacial existence of the mastodon, led me to examine this point with great care, and I state the conclusion without reservation. The lower halves of the legs were nearly upright, and in proper relative position, though somewhat sprawled. The bones of the feet were perfectly preserved, together with the distal portions of the lower shaft bones. The upper ends of these bones were somewhat decomposed. The humeri and femora, also poorly preserved, lay nearly horizontal at their respective legs, and the bones of the body and head lay, in a crushed and fragmentary condition, along the same level, about eighteen inches below the surface. Ribs, vertebræ, tusks and teeth were in proper place, and the latter were well enough preserved to identify the specimen as an adult and rather large individual of *mastodon giganteus*. The legs, being thrust into the mud, were best preserved. The body, exposed to the air, decomposed rapidly, and let the bones fall to the surface of the bog, where they were but partially protected. The overlying peat has been formed since the deposition of the skeleton, and might be taken as the measure of its antiquity, were the accumulation still progressing at its average rate. This however is not the case; the swamp, before drainage, had become so firm as to be sparsely covered by trees, and the rate of filling would, of course, diminish as the work verged on completion. There can be no question, however, that the creature lived and died long after the deposition of the drift on which the marsh deposits rest.

I am informed by Dr. J. B. Trembley, of Toledo, that a tooth of a mastodon was obtained from a marsh in Springfield, Lucas county. I was unable to ascertain the precise locality, but all the marshes of that town date from the formation of the lowest and most recent of the raised beaches; and it is almost certain that the tooth is not less recent than they.

CHAPTER XXII.

GEOLOGY OF WILLIAMS COUNTY.

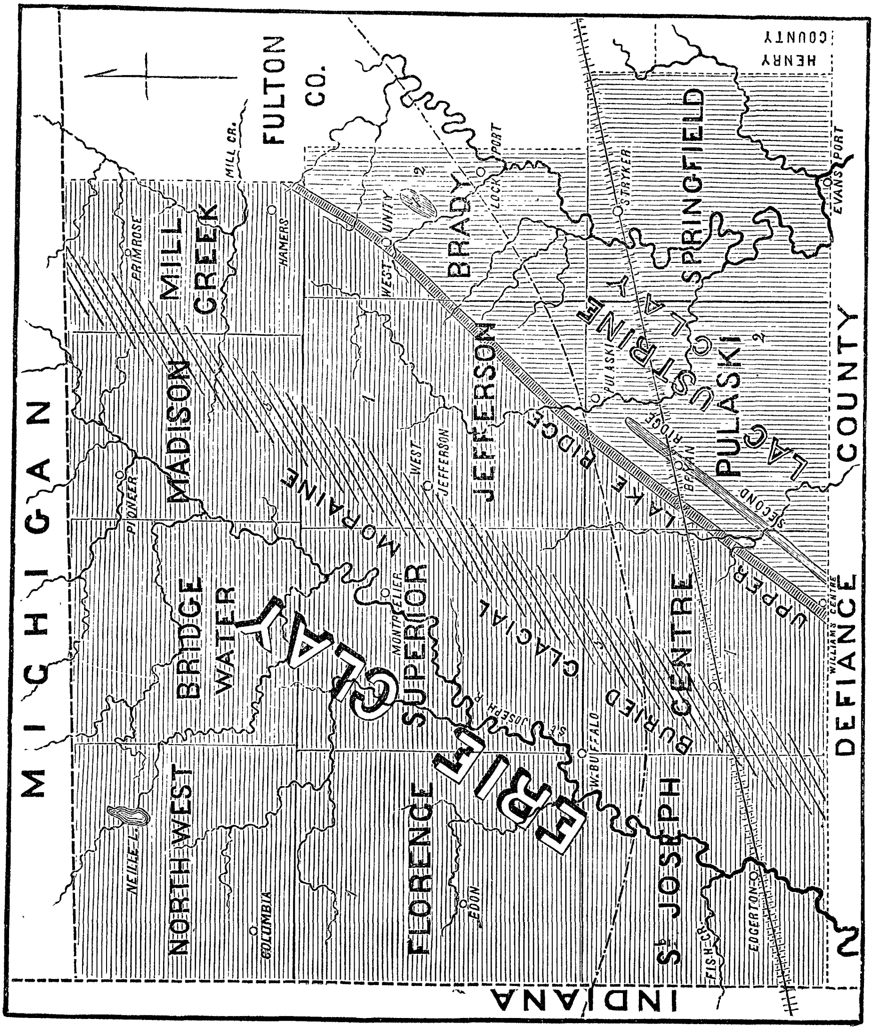
TOPOGRAPHY.

Williams county lies entirely within the broad, shallow valley that is drained by the Maumee river. In common with the adjacent counties north of that river, its surface has a general slope to the south-east; and the highest land in this portion of the state is in the township of North-west, where the general surface lies from 400 to 450 feet above the water of Lake Erie, while a few hills rise fifty feet higher. The opposite corner of the county is three hundred feet lower, the descent being gentle, and, with one notable exception, uniform throughout. This exception is occasioned by a ridge which crosses, in a north-east and south-west direction, just east of the St. Joseph river. Its geological aspects have already been noticed in the preceding chapter. Topographically, it is a mere swell on the surface of the plain, six or eight miles broad at the base, with a maximum height of fifty feet, and not differing in superficial characters from the adjacent country. All of the country west of this ridge is drained by the St. Joseph river, which flows south-westward to join the Maumee at Fort Wayne, Indiana. East of the ridge, the water is collected by Bean creek, which crosses the south-east corner of the county, and flows southward to the Maumee at Defiance. The small streams rise in the main from perennial springs, and are lively and clear, and the beds of all the streams are carved entirely in the drift.

GEOLOGICAL STRUCTURE.

The indurated rocks, being everywhere covered by a heavy bed of drift, have been reached in this county only by boring, and this at but one place. A well drilled for oil at Stryker, after traversing 129 feet of drift, met the Huron shale with a thickness of 68 feet, and underlaid by limestone. Combining this record with the railroad levels, the base of the

MAP OF WILLIAMS COUNTY.



Huron shale is shown to be here fifty feet below the level of Lake Erie. Comparing this, again, with the altitude of the same horizon, at various points along the Maumee river, it appears that its dip is to the north, or north-west, at the rate of seven or eight feet to the mile. In adjacent portions of Michigan the dip, so far as known, is in the same direction; and it is hence presumed to be continuous through the unexplored interval. There is reason to believe, too, that the gradual rise of the country toward the north-west is accompanied by a corresponding and equal

acclivity of the rock surface. It follows, as probable, that the higher land is underlaid by five hundred feet of strata superior to the base of the Huron shale; and that the upper portion of this mass belongs to the next succeeding group, the Waverly. The lower margin of the Huron shale is in every direction beyond the limits of Williams county.

The stratigraphical data are so unsatisfactory that the map of the county has been made to represent, instead, the features of the surface geology, which, in their relation to the distribution of soils, are of more interest and importance.

SURFACE GEOLOGY AND SOILS.

The general considerations involved in the surface geology of this and adjoining counties, are given in the preceding chapter, to which the reader is referred. It remains to consider the geology of the soils, which are, of course, independent of the underlying rocks, and referable exclusively to the drift. They are divided into two somewhat marked provinces by the upper beach ridge. This enters from Defiance county at Williams Centre, and, passing with a nearly straight course just west of Bryan and Pulaski, and through West Unity, crosses into Fulton county a half mile north of the "Fulton line."* Its soil is sandy, and in places objectionably light on the summit of the ridge, but the eastern slope affords everywhere a rich and highly-prized sandy loam, which shades gradually into the clay loam of the plain. Easy drainage, easy tillage, and the advantage of building sites at once pleasant and salubrious, led to the early occupation of this land, and it now bears prominently the visible marks of prosperity. A second ridge, lying a mile east of the other, and running from the south line to Bryan, presents similar characters; and some sand ridges lying east of West Unity, may be included in the same category.

West of the upper beach the surface consists of unmodified Erie clay, and the soils present all the variety of that heterogeneous deposit. The major part is a yellow or buff clay, with enough sand and gravel to render it arable and permeable. Patches of unmixed clay are frequent, but small; and, though sometimes friable, are more commonly very adhesive and difficult of management. Except in swales, the accumulation of

* The Fulton line was at one time considered as the southern boundary of Michigan, and serves to commemorate the disturbance, known as the Toledo war, that arose concerning it. It extends from the eastern limit of Lucas county west to the Indiana line, and, as it separates two independent and discrepant surveys, has been adopted at numerous points as township or county boundary. In Williams county, it divides the north tier of towns from the middle.

mold is inconsiderable, but the soil is retentive of vegetable manures, and gives a good return for their application. Carbonate of lime was originally very abundant, and remains on the more level portions, but appears to have been washed from the slopes. Sand is rarely predominant, but in Northwest a tract of two or three miles area is covered by a clean yellow sand. It has for the most part a sub-soil of clay so near the surface as to render the land valuable, but near Nettle Lake is deep and light. The country generally is rolling or undulating, and abounds with deep marshes, in which are extensive deposits of marl and peat or muck.

Along the St. Joseph river, and appearing alternately on the opposite banks, is a strip of flat, sandy land, nearly identical in character with the bottom land that forms the immediate bank of the river. It is, in fact, an ancient bottom, or flood-plain, of the St. Joseph, formed when its current was checked by lake water standing at the height of the upper beach. At Edgerton this deposit has a depth of forty feet, and its extreme width is about one mile. It can be traced northward as far as Pioneer, but above there is not distinguishable from the present bottom. Like most river bottoms, it forms a valuable soil, and is not subject to the disadvantage of occasional overflow.

East of the beach ridges, and between them, the plain is of a rich, friable clay loam, entirely stoneless, and varied near the ridges by streaks of sandy loam. It is formed of fine material derived from the Erie clay, and spread smoothly by lake currents. Lying so nearly level that the water of rains runs off but slowly, it has accumulated a rich store of vegetable mold, and needs but thorough drainage to develop its wealth. This covers the greater part of Pulaski, Brady and Springfield, but in the latter towns are some slight swells exhibiting the gravelly clay of the western portion of the county—truncated knolls of the Erie clay that were not covered by the lacustrine deposits.

ECONOMIC GEOLOGY.

MUCK, MARL, AND BOG-IRON ORE.

Of the marshes and swales that abound on the surface of the unmodified drift, and especially west of the St. Joseph river, a large number are without natural drainage. The rain water than has run into them has escaped by evaporation, leaving behind whatever material it brought from the surrounding slopes, the greater part being clay and carbonate of lime. The presence of the latter in solution in the water led to an abundance of molluscan life, by which a portion of it was converted into

the form of shells, producing the common shell marl. This is mingled in all proportions with clay, and is to be found in all but the shallowest basins. Over it, and representing chronologically the period during which vegetation has covered the marsh, is a deposit of muck or peat, usually still in process of formation. Interstratified with the marl have been found beds of bog iron ore, but as yet none of sufficient magnitude to be of economic importance. Their quality is untested.

The muck is at present the most valuable, as well as the most accessible, of the marsh products; for there is little of the rolling land that will not be improved by the use of vegetable manure. It has been so little probed that no estimate of its amount is practicable, but there can be no doubt that it will supply the demand for agricultural use for many generations. The accumulation of marl is equally great, though no heavy beds will be available until deep drainage shall have been resorted to for the reclamation of the marshes.

BUILDING MATERIALS.

Williams county contains no stone quarry, and the great depth of the drift forbids the hope that one may be discovered. In the northern and eastern towns bowlders have sufficed for the foundations of farm-houses, but most of the land east of the lake ridges lacks even these.

In brick-making little has been attempted. Probably few towns are without a suitable clay; but the best results are to be expected from the lacustrine clays and sands in the neighborhood of the lake beaches. Lime has been burned in small amount, by consumers, from the marl of the marshes, but its manufacture in quantity for architectural and agricultural uses has not yet been undertaken, and can hardly be conducted with profit until other interests shall have induced the drainage necessary to render the marl accessible in large quantity. How lime so produced will compare in quality and cost with that now imported from neighboring counties, cannot be predicted, but it is not improbable that the county will at some future day manufacture its own lime.

PETROLEUM.

The decided northward and westward dip of the rocks of the vicinity is plainly indicated by the various outcrops and well records, and leaves little expectation that the essential condition of an arched receiver will be realized in the indurated rocks.* It is not impossible, however, that

*The essential geological conditions for a valuable accumulation of oil are: 1st, an oil-producing rock; 2d, an overlying receptacle, covered by (3d), an impervious roof in the form (4th), of an arch or dome.

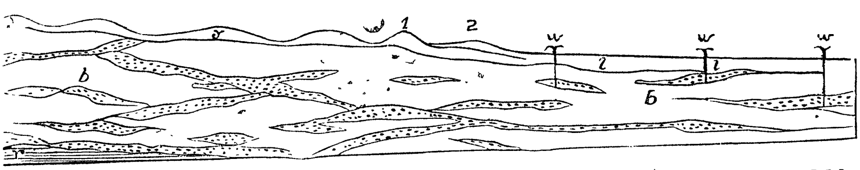
accumulations of rock-oil exist at the base of the drift. The subjacent black shale is highly bituminous, and is the recognized source, in other districts, of valuable collections of oil. Beds of gravel are common at the base of the blue clay, and any of these that is isolated, and completely covered by the impervious clay, so as to be traversed by no water-current, is a suitable reservoir for the reception of oil. With the thorough probing to which the drift is being subjected for water, the probability of the discovery of such a reservoir is constantly diminishing; but, should one be found, it is well to understand that no exploration below the drift will avail for its development.

WATER.

The entire subterranean water supply is from the sand and gravel beds of the Erie clay. Where the country is rolling, springs abound along the streams, and nearly everywhere water can be cheaply obtained by boring. In the western and northern parts shallow wells, ten to twenty feet deep, generally suffice, but in the remainder a depth of fifty feet is not unusual, and many wells exceed one hundred feet.

The famous Artesian wells of the Maumee valley, the first of which were made at Bryan, in 1842, have their source in the Erie clay. They have now become so numerous, and the search for them has been so general, that their distribution in this and the adjoining counties is pretty well defined, and some explanation thereof may be given. They are found in a belt of country which, in common with the other geological features of the vicinity, has a north-east and south-west trend. Its western limit is the more definite, and through Defiance county and the southern part of Williams, follows close to the upper beach line; the belt then bears more to the east, and terminates in Gorham, Fulton county. Its width varies from two to ten miles, and seems to be affected by the proximity of a deep-cutting stream, as the Maumee river or the lower course of Bean creek.

FIG. B.—*Ideal section, to illustrate the distribution of Artesian Wells in Williams county.*



1 and 2, 1st and 2d Beach Ridges; *l*, Lacustrine Clay; *y* and *b*, yellow and blue beds of the Erie Clay, with enclosed lenticular beds of gravel and sand; *w*, Artesian Wells.

The annexed cut, Fig. B, gives an ideal section of the Erie clay when crossed by the belt of Artesian wells. The beds of sand are sometimes isolated and dry, and sometimes connected in broad systems through which water percolates, following the descent of the land. West of the upper ridge it finds its way to the surface at many points, forming springs along the streams; and the water in neighboring deep wells rises no higher, or but little higher than these springs. East of the ridge, the unbroken Lacustrine clay cuts off the discharge through springs as far as the nearest deep-cutting stream. This taps the sand-beds and lowers the head for some distance, but the sand through which the water seeps affords sufficient resistance to maintain an artesian head near the ridge. The discharge, though copious, is sensibly limited. Every new fountain well diminishes the flow of those near it; and, as the number of wells in a locality increases, the head is lowered. I am informed by Mr. Hess, a well-borer of Bryan, that in that place it has fallen about three feet in the past seventeen years, so that many wells which originally flowed, now have to be furnished with pumps.

The source of this ever-welling water, artesian and otherwise, is, of course, higher than the discharge, and, consequently, west of the lake ridges. Its perennial flow suggests a distant reservoir, while the small percentage of its mineral constituents and their variable character, point to one near at hand. The superficial, yellow portion of the Erie clay is, in great part, permeable, and, storing a portion of the water that falls on it, yields it gradually to the underlying sand-beds wherever it touches them. This, the ordinary explanation of springs rising from the drift, seems to me quite adequate to account for the supply of these wells.*

The mineral impurities of the well and spring water of the country are as variable as the constitution of the clay from which they are derived. No analyses have been made, but the general facts are appreciable to the senses. The usual earthy carbonates, constituting it "hard" water, are always present, though not often in great amount. Oxide of iron, accompanied by sulphydric acid, is very common, and frequently in considerable force, giving a yellow coating to the spouts and troughs that convey the water. A few wells, in various localities, afford what is called "bitter water." This is rendered noxious, and, fortunately, at the same time unpalatable, by the presence of an iron alum, or perhaps copperas. One

* It was reported some years ago that fishes issued with the artesian water of Bryan. As it is not said to occur now, as the account was discredited by many citizens of Bryan at the time, and as it is inherently improbable, it is not deemed important to discuss the matter.

well is worthless, from the presence of a gaseous hydro-carbon, and I am told that one or two others are tainted by the same.

STRYKER MINERAL WATER.

In 1865 a well was commenced in Stryker, under the superintendence of Mr. William Sheridan, of that place, in search of oil. With some intervals, the work was continued until 1867, when it was abandoned, a depth of 860 feet having been attained. More recently, attention has been attracted to a heavily charged mineral water that was met in limestone, probably of the Hamilton group, at a depth of 230 feet. In February, 1870, an analysis was made by Prof. S. H. Douglass, of the University of Michigan, with the following result:

Analysis of Stryker Mineral Water.

	Grains per gall. (231 in.) of water.
Chlorid of Magnesium	118.96
" Sodium	231.86
Sulphate of Potassa	185.34
Carbonate of Lime	68.34
" Iron	9.93
Silica	2.63
Sulphydric acid	4.49
Total	621.55

Prof. Douglass adds: "The sulphydric acid had doubtless much of it escaped before the water reached me—it should have been determined at the spring."

The gas may be entirely distinct in origin from the water, as it was met at several points in the boring. It rises continuously, keeping the surface of the water in a state of ebullition. Periodically, a large volume finds vent at once, escaping with great force, and carrying the water with it in a foaming torrent. This continues for from ten to twenty minutes, when the flow of gas gradually diminishes to a minimum, and the water subsides to eight or ten feet below the level of the ground, from which position it slowly rises until the next discharge. If the well is left open, this occurs in about six hours, but, by partially closing the top, it can be indefinitely delayed. On the other hand, it can be induced, after a shorter interval, by agitating the water in such manner as to give it a vertical oscillation. It would appear that the gas collects in some reservoir over a body of water, which it gradually displaces. When the water is forced so low that a little gas can escape by way of the well, it rushes out so

rapidly that it blows away some of the water from the opening; it can then escape still more rapidly, and by this reciprocation the aperture is cleared, and a large volume of gas discharged at once. From the repetition of this process arises the periodicity of the overflow. By checking the escape of the gas above, it is prevented from rushing violently out of its store house, and an equilibrium is maintained; and it is easy to see how the agitation of the water would serve to precipitate the emission. This explanation is, of course, not demonstrable at the well, but is at present the only one suggested that seems to accord with the phenomena.* A trifling amount of petroleum rises with the water; and, at the commencement of the discharge, the odor of carbureted hydrogen is plainly discernible, mingled with that of the sulphydric acid, but it is afterwards lost. As the discharge progresses, there is a change likewise in the taste of the water.

The well-known narcotic properties of the gas have been illustrated in the putting to sleep of several visitors.

VEGETATION.

The primitive forest growth was tall and compact throughout the county, with the exception of a few hundred acres of "oak openings" (partly on clay and partly on sandy soil) in the town of Northwest. There are no prairies.

On the unmodified drift the most abundant forest trees are white elm, beech, white and bur oak, white ash, sugar maple (the black variety being strongly marked), whitewood (*Liriodendron tulipifera*, L.), Linden, and—confined to the deep marshes—tamarack. Less numerous, but still abundant, are sycamore, black oak (*Quercus tinctoria*, Bart.), red oak, (*Q. rubra*, L.), chestnut oak (*Q. castanea*, Willd.), swamp maple, cherry (*Prunus serotina*, Ehrhart), black ash, red elm, black walnut, ironwood (*Ostrya Virginica*, Michili), and water beech (*Carpinus Americana*, Michx.). The buckeye is frequently met with, and the same may be said of the honey locust, blue ash (*Fraxinus quadrangulata*, Michx.), sassafras, several species of hickory (*Carya alba*, Nutt., *C. sulcata*, Nutt., *C. glabra*, Tow., and probably also *C. amara*, Nutt., and *C. tomentosa*, Nutt.), butternut, striped maple (*Acer Pennsylvanicum*, L.), pin oak (*Q. palustris*, Du Roi), hackberry, mulberry (*morus rubra*, L.), two species of aspen (*Populus tremuloides*, Michx., and *P. grandidentata*, Michx.), poplar (*P. heterophylla*,

* Experiment was made with an apparatus intended to reproduce in miniature the supposed conditions. While a periodic discharge was readily obtained, the test was not entirely satisfactory, as the tubes used were so small as to give capillarity considerable influence.

L.), cotton-wood, and a number of willows not specifically identified. The Kentucky coffee-tree (*gymnocladus Canadensis*, Lam.), and the box elder (*negundo aceroides*, Moench), are occasionally found on bottom land. Individuals were probably seen of the scarlet oak (*Q. coccinea*, Waug.), but the identification was not satisfactory. Birch was sought in vain.

The following enumeration of species of the undergrowth is doubtless far from complete. Dogwood (*Cornus florida*, L.), alder (*Alnus incana*, Willd. ?), common elder, black haw, hazel (*Corylus Americana*, Walt.), red-bud (*Circis Canadensis*, L.), wild plum (*Prunus Americana*, Marsh), choke cherry, black thorn, cockspur thorn, crab apple, poison sumach, staghorn sumach, dwarf sumach, prickly ash, button-bush (*Cephalanthus occidentalis*, L.), hop-tree, bladder-nut, shad-bush. The three last mentioned are given on the authority of Mr. J. H. Klippart.

Crossing the beach line to the more level country, less change is found in the variety of species than in their relative abundance. The oaks, the sugar maple and the beech become less prominent. The tamarack disappears entirely, and the swamps are occupied by elm, swamp maple and black ash instead. The pepperidge and papaw are added to the list, though neither is abundant, and the latter is of inferior size. On the ridges a few corky white elm (*ulmus racemosa*, Thomas) were noted.

ANTIQUITIES.

At the confluence of Silver creek with the St. Joseph river, is a group of low tumuli. They were opened by Mr. G. K. Roy and others, of Pioneer. Two contained each a single skeleton, but no bones were found in the others. The only implements discovered were a stone hatchet, with groove for a withe, and some wrought flints.

CHAPTER XXIII.

GEOLOGY OF FULTON COUNTY.

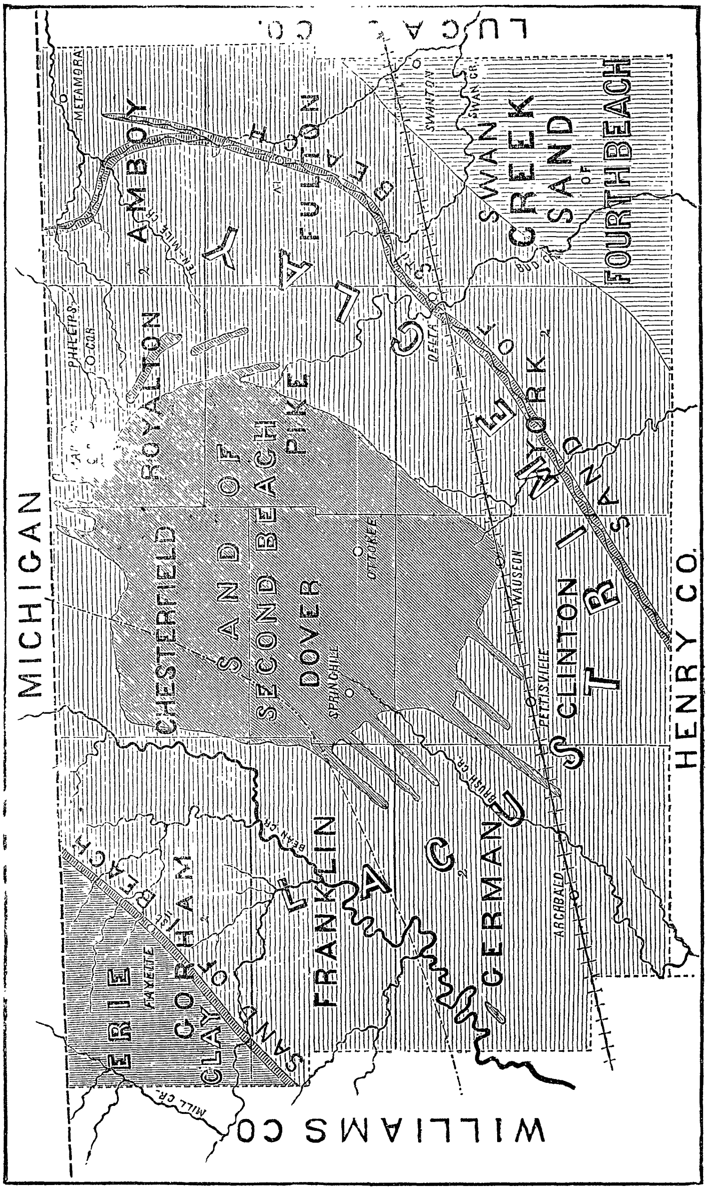
TOPOGRAPHY.

The general slope of the surface is to the south-east and quite moderate. The lowest land, in the town of Swan Creek, lies 95 feet above Lake Erie, and the highest, in north-western Gorham, about 250 feet. In the center is a sandy plateau with an average elevation of 200 feet, and drained by streams flowing toward all points of the compass, save the north-west. The only water course rising beyond the limits of the county and traversing it, is Bean creek, which passes, with a south-west course, west of the plateau, and finds its way to the Maumee river. Save on the high land in Gorham, the streams are somewhat sluggish, and the smaller are liable to fail in time of drought.

GEOLOGICAL STRUCTURE.

Little can be said of the bedded rocks of Fulton county. They are covered by a heavy sheet of drift, nowhere known to be less than fifty feet in depth; and have been reached in boring at a few points only. These are mainly near the line of the Air-Line Railroad, and the rock struck was, in each case, the Huron shale—either the characteristic black shale or associated masses of pyrites. At Delta it was drilled through in boring for oil, and found to have a thickness of 55 feet. Under it were found 20 feet of soft gray shale, representing the Hamilton group, while the upper part of the Corniferous group appeared to be quite argillaceous. Comparing the altitudes of these beds in the neighboring counties, Henry and Lucas, where they outcrop, we find their general dip to be gently to the north and west, and it is probable that its continuance carries them under the Waverly group, within the limits of the county. So far, then, as can be judged from the meagre data available, the major part of the county is underlaid by the Huron shale, and this is covered in the north-west by beds of the Waverly group.

MAP OF FULTON COUNTY.



In boring for water on the farm of Mr. F. Ford, near the south line of Gorham, cannel coal was struck, and is reported to have been pierced to a depth of three and one-half feet, when water was found, and the work was stopped. Overlying it was the blue clay of the drift, but, as the

underlying material was not determined, there remains a doubt whether the coal was in its original position, or was merely a drift bowlder transported from the Michigan coal-field. The latter supposition is, at present, far the more probable. The nearest recognized outcrops of the Coal-measures are forty miles distant in Jackson county, Michigan.

The assumed southern limit of the Waverly group, and northern limit of the Huron, is indicated on the accompanying map by a broken line; but the superficial features only, which are better known, are distinctly indicated.

SURFACE GEOLOGY AND SOILS.

The surface geology has already been treated in connection with that of the surrounding counties, (Chap. XXI.) and it will be necessary to refer here only to its topography, as related to that of the soils. As in the county just described, the soils are referable entirely to the drift and lacustrine deposits, and have no dependence on the indurated rocks. They may be classified, at least logically, as, 1st the drift clays, 2d the lacustrine clays, 3d the beach ridges, 4th the deep sands or dunes, and 5th the shallow sands.

The unmodified Erie clay appears in north-western Gorham, and presents the same features as in Williams county, except that the deep marshes are wanting or nearly so. The beach line which limits it, crosses the west line of Franklin township, at the Methodist cemetery, a half mile north of the "Fulton line," and runs north-east to Fayette, and thence to the Michigan line, which it intersects three miles west of the east line of Gorham.

The lacustrine clays have resulted from the redeposition of the Erie clay, and differ from it in that they lack the coarser materials, are more homogeneous, and are deposited with a flat and often nearly level surface. They cover the major part of the county, including all areas not otherwise assigned. In Franklin, German, southern Clinton and York, and eastern Amboy, their extreme flatness is remarkable, and it is often impossible by the eye to determine the direction of the slope.

The beach ridges have only a small area, but crossing many farms otherwise destitute of sand, they afford a desirable variety. Besides the upper ridge, whose position in Gorham has just been described, another, constituting the third beach, is well defined. Beginning on the Michigan line, three miles west of Metamora, it curves abruptly first east and then south. Proceeding nearly south to the village of Ai, it then curves so as to assume a course a little west of south-west, touches the north-west corner of Swan creek, passes through the village of Delta, and,

leaving the county near the middle of Clinton, runs to Ridgeville, in Henry county. In its general character it is sandy, but at several points where its dimensions are small, it is formed of fine gravel. From Ai, a low, gravelly ridge runs northward to within two miles of Metamora, and abruptly terminates. These gravel and sand ridges are especially available for roads, and so used at numerous points. In the north-east part of German are several parallel ridges of fine sand, that are perhaps beaches. They run from the edge of the central sandy plateau south-west over the clay plain, in which they are finally lost, and may be regarded as successive bars, formed during the accumulation of the dunes.

In the regions of the deep sand, a large part of the surface consists of a succession of knolls or dunes, and short ridges, the latter being, in rare instances, traceable for a distance of several miles. Interspersed with these, and enclosed by them, are numerous marshes or wet prairies, large and small, which are slowly building up their surfaces with accumulating muck. When first occupied by the whites the only trees on these tracts were oaks, and these so sparsely set that their tops, as a rule, did not interlock, and "a wagon could be driven in any direction." This gave the country the name of "oak openings." With the discontinuance of the annual fires set by the Indians, a dense growth of oak sprung up in many places, but the lightest of the sand has acquired only a sparse and scrubby undergrowth. The drier of the prairies are now crowded with young aspens, which also date from the cessation of the fires.

The deep sands cover a fourth part of the county. The principal tract is central, including central and southern Chesterfield, nearly all of Dover, the northern fourth of Clinton, the western half of Pike, and a small area in south-western Royalton. In the south-east the county limits include a portion of a much larger district, that forms a broad belt in Lucas, Henry and Wood counties. In Fulton county it covers the south-eastern two-thirds of Swan creek, and a small portion of York.

There can be no doubt that this sand, of whatever depth, rests on clay, and all around the margins of these tracts are belts of country, often several miles in width, where the sand is thinner, so that the underlying clay may be met in digging a few feet, and forms an impervious sub-soil to check the leaching tendencies of the sand. These belts are as heavily timbered as the clay lands, and at their margins pass gradually into them.

ECONOMIC GEOLOGY.

The *water* supply in the deep sand district is derived by shallow wells from the sand. Elsewhere recourse is had to deep-seated reservoirs in

the Erie clay, and these are sought with the auger. In many instances the Erie clay has been pierced to its base without success, but more commonly water is found at the base, if not above. There are no surface indications, nor other data, from which to anticipate results, and it is a notorious fact that, of two holes bored but a few rods apart, one may furnish an abundance of water, and the other none. When reached, the water generally rises nearly to the surface, and in some limited districts overflows, making Artesian wells. The belt of these, already described as crossing Williams county near the upper beach ridge, extends into Fulton county between the ridge and Bean creek, crossing Franklin, and terminating in Gorham. A single fountain well is known in the south part of Clinton. The water has the same general character, and the same variety, as that of Williams county; and it is unnecessary to repeat the description already given.

Clay, suitable for brick-making, can be found in abundance in every township, and a quality adapted to the manufacture of tile is not uncommon. As yet but few bricks have been made, and no drain-tiles, nor am I aware that any of the latter have been used. The importance of thorough under-drainage to the attainment of the best results in agriculture, now so generally recognized, is especially marked in such a county as this, where it is by the very flatness and consequent saturation of the soil that its natural wealth has been fostered. This excessive moisture has now become an evil, and must be obviated to secure reliable crops and easy tillage. Endowed with no natural facilities for manufacture or commerce, but simply with a fertile soil, the province of Fulton county is the production of food, and whatever will forward her agricultural interests is of vital consequence to her. Viewed in this light the manufacture of tile appears to be of leading importance, and the day cannot be distant when it will be conducted on an extensive scale.

Peat or *muck* is stored in moderate quantity in the marshes of the sand districts, and is doubtless destined to serve as a dressing for the adjacent light sand.

Marl is found in marshes, upon the borders of the sand areas, where there has been some drainage from the clay land, but it is not to be expected in depressions entirely surrounded by sand hills.

Bog Iron Ore has been found in similar situations, and probably exists in considerable beds, to be discovered in the progress of the reclamation of the marshes by deep ditching.

That *Petroleum* need not be sought is sufficiently indicated by the experimental borings that have been made in this and adjoining counties. That it may not be found is not so certain. Borings for water, that

reached the underlying black shale, have in several instances penetrated at the bottom a gravel saturated with oil, and the discovery of a local accumulation would not be anomalous. The remarks made in regard to petroleum prospects in Williams county are equally applicable to Fulton.

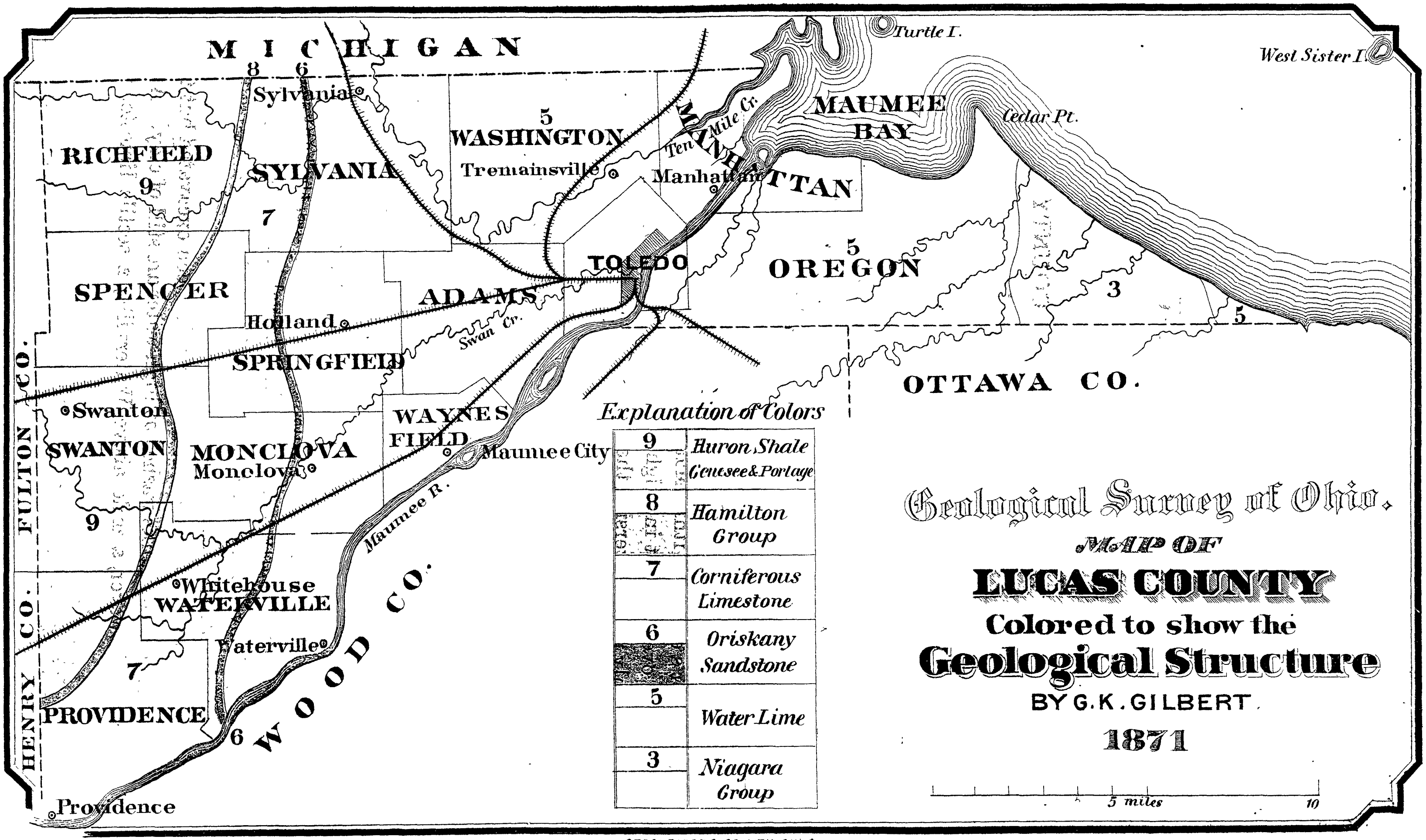
VEGETATION.

The lacustrine clay plains support a heavy forest growth, in which no single tree predominates. White elm, black and white ash, sugar maple, beech, linden, sycamore, whitewood, and white, bur and black oak are abundant, and a great variety of other trees are frequently met with. Of the forty or more species of forest trees enumerated as occurring in Williams county, all but the tamarack were noted in Fulton also.

Where the clay is overlaid by a few feet of sand, on the borders of the openings, the weight of timber is no less, but the elm, basswood, beech, etc., become rare.

The original arboreal vegetation of the deep sands is as poor in species as in individuals, comprising merely the white, red, bur and barren oaks (*Quercus alba*, L., *Q. rubra*, L., *Q. macrocarpa*, Michx. and *Q. nigra* L.). The white oak and bur oak, which are common to the adjacent timber, and there, with large, straight trunks, vie with the surroundings trees in height, are here comparatively small and low—their trunks often crooked, their branches gnarled, and their tops rounded in form, in response to the abundance of light from all directions. The red oak has the same form, and doubtless, also, the barren oak, but of the latter species I noticed no large individuals. On the more fertile portions of the sand tracts, there is a vigorous and dense growth of young oaks, principally of the white and red species, that has sprung up since white occupation stopped the burning of the under-growth. Aspens (*Populus tremuloides*, Michx., and *P. grandidentata*,) are springing up in great numbers on the prairies. Their light, down-covered seeds, flying everywhere with the wind, enable them to possess promptly any territory that has freshly become available.*

* It is noteworthy, as bearing upon the theory advanced by Prof. Winchell, in regard to the preservation of seeds in the drift, that the first trees to grow on newly bared drift are commonly (so far as my own observation has gone, always) of the genera *Salix* and *Populus*—genera which distribute their seeds with peculiar facility.



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CHAPTER XXIV.

GEOLOGY OF LUCAS COUNTY.

TOPOGRAPHY.

The surface of Lucas county is a plain, broken only by the narrow channels of its streams. The highest land lies along the west line of Richfield, and has an elevation above Lake Erie of about one hundred and forty feet. Going south along the county line to Providence, there is a descent of fifty or sixty feet, and from this line eastward a general and even slope to the lake. On the lake front the slope extends quite to the water's edge. Within Maumee Bay there is a bluff of clay, but it is nowhere over ten feet in height.

The only river traversing the county is the Maumee. From Providence to the south line of Monclova township, it flows over nearly level strata of the Corniferous and Waterlime formations, descending, in fourteen miles, fifty-five feet. The head of slack water is at Maumee City, fourteen miles from the mouth of the river. The last appearance of rock in place in the bed of the river is two and a half miles below Maumee City, where a limestone ledge with a north and south trend forms the "Rock Bar," eight feet below low water. From this point the bottom is composed of soft materials, sand and clay, the former a deposit by the river itself, the latter the Erie clay. The average width at the summer stage is one hundred rods at the slack water, and fifty rods above, and the river is readily forded on the rifts. At several points, the banks separate to a distance of nearly a mile, and the interval is in part occupied by low islands, or by flood plains, but, on the whole, the bottom land is of remarkably small extent.

Where the bed is of rock, it has generally been excavated but three or four feet, and the banks washed at high water are still of clay. At Roche de Boeuf, however, a mile above Waterville, a sectile limestone of the

water-lime group presents a bluff of thirty feet. At this point is a deserted channel that once carried, or at least shared, the water of the river, but is now thirty feet above it. It makes a short detour from the left bank, passing around a remnant of the bluff, that—once an island—now remains an isolated hill. Two miles below Waterville the same phenomena are repeated, and the insular character of the hill has been recognized in the name "Presque Isle," given it by the early French settlers.

The minor streams all flow eastward, and only Swan creek joins the Maumee. They are not spring-fed, and either dwindle very small, or fail entirely in dry seasons.

GEOLOGICAL STRUCTURE.

Lucas county exhibits the following series of rocks:

Huron group (lower part),
Hamilton group,
Corniferous group,
Waterlime group,
Onondaga salt group,
Guelph group.

The upper three groups are considered equivalent to the lower portions of the Devonian System of Europe, and the others are classed with the Upper Silurian.

The *Guelph group* immediately overlies the Niagara limestone of the New York System, and is now classed as a sub-division of the Niagara formation. While there are no rock exposures in the eastern townships, and the few borings that have reached the rock afford no satisfactory information,* enough outcrops have been observed in the neighboring portion of Ottawa county, to render it highly probable that the Guelph beds underlie a considerable part of the town of Oregon. The limits traced on the map are of course hypothetical.

The Onondaga Salt group has not been separated from the Waterlime in this county, and there is some doubt as to its occurrence. At Genoa,

* An attempt was made to ascertain the age of the limestone underlying Toledo, by comparing the record of the deep well drilled at Toledo, with those of oil wells sunk at Waterville and Whitehouse, Lucas county, Texas, Henry county, and Stryker, Williams county, all of which were started in determined formations. The discrepancies among these records are so great that a satisfactory correspondence between the beds of no two wells was made out; and the only result of the comparison is the conclusion that well-sections, when not accompanied by samples of the materials removed, are to be used with great caution.

Ottawa county, characteristic Waterlime fossils (*Lepuditia alta, con. sp.* and *Atrypa sulcata, Vauux.*) are found but a few feet above the Guelph limestone, and west of this point the base of the Waterlime series has not been seen.

The *Water-lime group* is exposed at many points. From the west line of Waterville, to slack-water at Maumee City, it forms the bed of the Maumee, presenting a series of variable, sectile, argillaceous limestones, with numerous local flexures, but no decided general dip. The same beds are exposed on the plain near Maumee City, in the bed of Swan creek at Monclova village, and at Fish's quarry in northern Monclova. In Sylvania, Ten Mile creek washes the Waterlime for some distance, and it is further exposed in the road west of the village, so as to afford the following section:

		FEET.
3.	Alternations of hard, gray, and soft drab sandstones; beds thin and uneven*..	40
2.	Massive, buff limestone (in part brecciated), with many small lenticular cavities, and some chert nodules..	30
1.	Gray, shaly limestone (part)	6
	Total	76

The outcrop of the overlying *Corniferous group* forms a belt west of the Water-lime. The line of junction crosses Sylvania, Springfield, Mon-

*I append the detailed notes of this series, taken along the ditch beside what is known as the Metamora road, one and a half miles west of Sylvania village. They are of little moment, except as they illustrate the uneven character of the deposit. At other outcrops the series is recognizable as a whole, but the individual components cannot be identified.

		FEET.
k.	Hard, drab limestone, with flinty fracture	3
	Not seen	3
j.	Hard, light-gray limestone	2
i.	Soft, cream-colored limestone	2
	Not seen	2
h.	Hard, dark-gray limestone	4
g.	Light-gray, porous limestone	1
	Not seen	4
f.	Soft, buff limestone, with flint nodules	1
e.	Hard, light-gray limestone	3
d.	Hard, dark-gray limestone	3
	Not seen	2
c.	Hard, dark-gray limestone	6
b.	Greenish gray limestone	3
a.	Soft, buff limestone	1
	Total	40

clova and Waterville in a southerly direction; and the superposition of the groups can be seen at Sylvania, at Fish's quarry, and in the bed of the Maumee. Two miles west of Sylvania village is a rocky ridge, slightly prominent above the drift, extending over two miles in a north and south direction, and exhibiting all the members of the Corniferous group. They are:

		Feet.
6.	Dark, bluish gray, sectile limestone, with crowded fossils (part)	5
5.	Thick-bedded, open, buff limestone, with white chert	25
4.	Drab limestone, beds 6–10 inches	50
3.*	Alternations of hard, arenaceous limestones with fine-grained gray limestones	52
2.	Massive, friable, white sandstone, (glass sand)	20
1.	Soft, massive, cream and buff limestone, with fossils at top	12
	Total	164

The full thickness of the upper bed is not shown. At Whitehouse fifteen feet are seen, but the upper limit is nowhere exposed.

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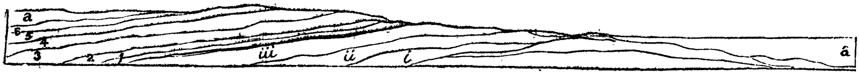
*The following are the sub-divisions of the lower members at Sylvania, also measured along the Metamora road:

			Feet.
3.	*l.*	Soft, gray sparry limestone	1
	k.	Soft, fine-grained, gray limestone, occasionally mottled with a purplish tinge; with a delicate stylolitic marking; thin-bedded	16
	j.	Hard, nearly white, arenaceous limestone, with purplish mottling	2
		Not seen	6
	i.	Soft, gray limestone; same as 3 *k*	2
		Not seen	3
	h.	Light gray, fine-grained limestone; slightly cellular and with some sand	2
	g.	Arenaceous limestone; same as 3 *j*	4
	f.	Fine, hard, ash-colored limestone	1
	e.	Dark drab, arenaceous limestone	1
	d.	White, arenaceous limestone; same as 3 *j*	2
	c.	Fine, hard, ash-colored limestone	1
	b.	Gray limestone; same as 3 *h*	6
	a.	Arenaceous limestone; same as 3 *j*	5
2.	*b.*	White, massive, friable sandstone	15
	a.	Drab, decomposing, arenaceous limestone	3
		Not seen	2
1.	*b.*	Cream-colored, sparry limestone, highly fossiliferous	1
		Not seen	3
	a.	Compact, massive, buff limestone	8

FIG. C.—*Section of Limestone Ridge in Sylvania.*



i, ii, iii, beds 1, 2 and 3 of the Water-lime group; 1, 2, 3, 4, 5, 6, beds 1 to 6 of the Corniferous group; a, a, Drift.

At Sylvania all the beds dip rapidly to the west, and their outrcrops, except a part of No. 6, can be noted in the space of a mile. Southward the dip diminishes, and the belt of outcrop becomes broader; and where it leaves the county in Providence, it is not less than five miles across. Nos. 2 and 3 outcrop at Fish's quarry, in the north of Monclova, Nos. 6 and 5 at Whitehouse, and No. 3 two miles east of Whitehouse. In the bed of the Maumee the glass sand (No. 2) is seen a few rods east of the east line of Providence, and the successive strata appear in order as we ascend to Providence dam, which rests on the buff limestone (No. 5).

Fossils occur in nearly all the beds, but are especially abundant in the highest and the lowest. Few were collected, as good specimens are rare; but of those that were procured, Mr. F. B. Meek, the Paleontologist of the Survey, distinguished thirty-six species of invertebrates. Twenty-four of these were found in the upper limestone (No. 6) at Sylvania and Whitehouse; among them *Strophodonta hemispherica*, Hall, *S. demissa, Con. sp.*, *S. Pattersoni*, Hall, *Productus spinulocostatus*, Hall (?) *atrypa reticulatis*, L., *A. aspera*, Schloth., *Spirifer Grieri*, Hall, *S. nacra*, Hall, *Conocardium trigonale*, Hall, sp., *Euomphalus De Cewi*, Billings, and *Teutaculites scalaris*, Scloth. The fine-grained limestone strata of bed No. 3 yielded a half dozen species, including some new forms. A single stratum of the lowest bed (No. 1) afforded a number of fossils at a single locality in Sylvania. Mr. Meek identifies among them *Strophodonta hemispherica*, Hall, *S. demissa*, con. sp., *Chonetes mucronata* (var. *laticosta*), Hall, and *Platyceras carinatum*, Hall, while undetermined species are referable to the genera *Heliophyllum*, *Plylodictya*, *Fenestella* and *Onychodus*.

The fishes that so abound in the corresponding beds at Sandusky and other points east of the great anticlinal axis, are but meagerly represented. A few teeth of *Onychodus* have been found in beds 1 and 5; and the gray limestone, No. 6, yielded at Sylvania a single cranial bone, referable, in the opinion of Dr. Newberry, to no described genus.

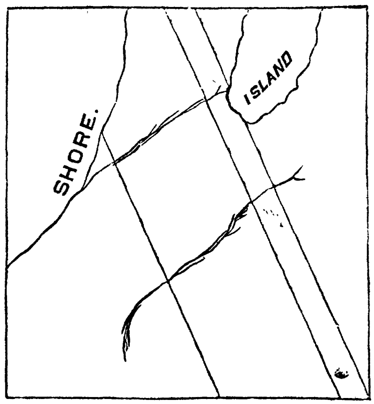
The *Hamilton group* is not exposed, but is believed to be represented by a bed of soft gray shale, outcropping in a narrow band along the edge of the Huron shale. At Delta, Fulton county, where it was traced in boring for oil, it has this character, with a depth of twenty feet.

The *Huron shale* is a hard, bituminous black shale, stratigraphically

the highest rock in the county. It is entirely concealed by the drift, but has been reached in boring for water at various points in Richfield and Spencer. In the latter town its ascertained depth is reported to be sixty-five feet. Its dip is to the west, and it probably underlies Richfield, the major part of Spencer, Swanton, and portions of Sylvania and Providence.

Joints, etc.—Joints are not numerous, and the only well-marked system was seen in the bed of the Maumee. The sectile beds of the Waterlime group are there divided by a number of very straight, vertical joints, bearing uniformly N. 50° W. to N. 55° W. No dislocations have taken place along these lines, though the same rocks have at several points been fractured since induration. The broad exposure which the river bed affords shows that the rocks lie in a system of low swells, of which the longer axis trends in general N. N. E. and S. S. W. The anticlinals are occasionally fractured. The annexed diagram, Fig. D, represents one of these fractures about fifteen rods in length, together with the exposed portion of a longer one; and shows their relation to a system of joints.

Fig. D.



Anticlinal fractures, and joints, in bed of Maumee river, near Waterville, Seneca county.

Stylolitic markings appear on all the limestones of the Corniferous, except the lowest. Those of the building stone (No. 5) usually exhibit vertical flutings one or two inches high, which are common along lines of bedding. On the fine-grained limestones that alternate with the arenaceous beds (No. 3), the markings are peculiarly delicate and beautiful. A specimen from Fish's quarry, intermediate between stylolite and slickensides, is of interest from the corroboration it affords of the theory for their origin advanced by Prof. O. C. Marsh, of New Haven. It exhibits a surface of bedding, along which a slight motion has occurred in a nearly horizontal direction, producing a system of minute parallel fluted surfaces, inclined at an angle of 10° to the bedding. These surfaces are accompanied by the usual dark film, and the film and stylolite terminate abruptly and on the same line. The film constituted an unguent, and induced a local slipping, as the result of a pressure that, when the film was absent, produced only an unrecorded yielding of the mass.

SURFACE GEOLOGY AND SOILS.

The surface geology has already been discussed at another place [Chapter XXI.] The soils are geographically arranged in four divisions, one of which—a broad, branching belt of sand—separates the other three, which are characterized by clay.

The general form of the sand belt is shown on the map of the raised beaches (page 549), but its limits considered as a soil area cannot be definitely platted, as the passage is often gradual from sand to clay. Its general course is south-west across Sylvania, Springfield, Spencer, Scranton and Providence, with a width of from five to ten miles. From Sylvania a branch three or four miles broad runs south-east, across Adams, to the Maumee river. Over the principal and central portions the sand is deep, presenting all the features of dunes, open timber, wet prairies, &c., incident to its prolongation in Fulton county. It is unnecessary to repeat here the description already given in the chapter on this county. The bordering belts of shallow sand with clay sub-soil are likewise of the same character.

The north-west corner of the county, including nearly all of Richfield, and parts of Sylvania and Spencer, has an unbroken, flat surface of clay, either pure or mingled with fine gravel. A second clay area lies along the Maumee in Waterville, Monclova and Waynesfield, and runs north so as to include the south-east part of Springfield. It is very irregular in form, and near its margin is traversed by numerous low sand ridges—outliers of the adjacent sand tract. It is probably continuous, through Wood county, with the third and principal clay plain, which comprises Oregon, Manhattan and the chief part of Washington. These two plains are portions of a large district in Lucas, Ottawa, Sandusky, and especially in Wood county, which has long borne the name of "the Black Swamp"—"swamp," because its retentive clay, lying nearly level, held the water of rains on its surface for a long time; "black," because by this saturation the entire decay and dissipation of vegetable substances upon its surface has been arrested, and a great amount of carbonaceous material accumulated in its soil. In the possession of these characteristics the black swamp does not differ essentially from numerous other clay plains in the Maumee valley, which, in common with it, have received their level surfaces from the action of the lake water by which they have in former times been covered; but it possesses them in a pre-eminent degree. Having been longest submerged, its grading has been most thoroughly accomplished, and nothing remains prominent above its level surface but the highest points of the bed-rock, which project like islands above a

water surface. None of these are seen however in Lucas county, and there is an even slope of four or five feet to the mile toward the lake. The predominant clay is diversified by streaks having a decided admixture of sand, but these are comparatively unimportant.

The vegetable mold is not confined to the immediate surface of the soil, but is found mingled with the clay below, in gradually decreasing proportions, so as to impart its color to a depth often of several feet. The mixture must be due in part to the decay of roots that have penetrated the soil, but the chief agency is that of burrowing animals and notably that of fresh-water lobsters or cray fishes, which abound on the undrained plain, and, in very dry seasons, dig vertical holes deep enough to reach moisture, bringing the excavated earth to the surface, and thus mingling the upper and lower portions. The process is necessarily slow, but it is none the less effective; and the incorporation of the organic with the inorganic components of the soil, that has been effected by it, is not the least important of the means that have conduced to give the Black Swamp region the enduring fertility with which it is so generally and so justly accredited.

ECONOMIC GEOLOGY.

BUILDING STONES.

The thick-bedded, buff limestone (No. 5 in the schedule of the Corniferous beds), is the most important building stone of the county. While it contains no sand, and the title of "sandstone" popularly given to it is entirely inapplicable, it yet has so large a percentage of impurities as to be quite unfit for lime. Its texture is open, not from the loose aggregation of its particles, but from the dissolution of some of its original components. Under the glass it shows numbers of minute cavities having the form of crinoidal and other organic fragments. The color of the stone when dry is a pale buff, and it is not prone to discoloration. The strata are from ten to twenty inches thick, and readily removed in large blocks. While wet it is very soft and easily wrought. Though quite porous, and by no means hard, it has nevertheless proved its durability by the practical test, and has been extensively used for abutments and like heavy work with the best results. It is now proposed to saw it into slabs for lintels, sills, &c., and I see no reason why it should not find favor for a great variety of architectural uses. The cost of quarrying is somewhat enhanced by the presence of chert nodules, which, for the best work, make it necessary to discard a portion of the stone, but, as they do not occur indiscriminately, but are arranged in regular horizontal rows, they can, with care, be surely avoided. They are lenticular in form, from one

to three inches thick, and commonly consist of nuclei of dark translucent flint, enveloped in a white, opaque, crumbling, apparently silicious substance, cleaving from the limestone. The principal quarries are at Whitehouse, whence the stone is shipped westward along the line of the Toledo, Wabash and Western railroad. At Providence it is worked in the bed of the river during low water, and a few boat loads are shipped every year by canal. At Sylvania it is the highest of the beds quarried, and comprises the openings on the farms of Mr. Lee, Mr. Shay, and Mr. Kenyon Cooper.

Another useful building stone is afforded by the arenaceous limestone beds which overlie the glass-sand (No. 3 of the Corniferous series). The contained sand grains are peculiarly translucent and rounded, and, where separated by the weathering of the rock, form a white sand. The stone has a buff color, with purplish mottlings, where quarried near the surface; but several openings have shown that the deeper portions, lying below the reach of the air, are gray or bluish. The difference is a familiar one, and finds its counterpart in the yellow and blue tints of the upper and lower portions of the clay beds. The color is in each case given by the contained iron. In the lower parts, the iron exists as the protoxide (black); while near the surface it has acquired oxygen from the air, and changed to the peroxide (yellow). The most extensive quarrying has been done by Mr. George Loeb, two miles east of Whitehouse, and by Mr. William Fish, two and one-half miles south of Holland Station. Near the former quarry, Mr. A. Shear, near the latter, Mr. W. S. Holt, and in Sylvania, Mr. John Rampus have openings in the same bed. Some stone of this layer has also been removed from the bed of the Maumee, three miles below Providence.

The total production of stone for the county amounted, in 1869, to nearly 7,000 yards, including all grades, valued at the quarries at about $7,500.

Lime is derived from several different beds of the Corniferous group, and the upper portion of the Waterlime. At Whitehouse, the blue, fossiliferous bed (No. 6) of the Corniferous furnishes a third of the production of the county. It has been in part shipped westward by rail to Napoleon, Defiance, etc., but the principal market is among farmers and others of the vicinity, and nearly all the other kilns furnish lime only for local consumption. In Sylvania the drab limestone, (No. 4) of the Corniferous, traverses sections 7, 8, 17 and 20, and is worked at several points. It is also used at Providence. Various beds of the waterlime are burned at Maumee City, at Waterville, at Monclova village, and at Fish's quarry.

So far as I am aware, all these form efficient and durable cements, though they differ widely in purity, color and facility of use. None of them have found favor in the Toledo market, where the masons demand, after the essentials of whiteness and freedom from lumps, that a lime shall "work cool," that is, slake without great evolution of heat, and set slowly. For this reason the lime manufactured at Genoa, Ottawa county, from the highly magnesian limestones of the Guelph group, is especially esteemed. An attempt was made, in connection with this work, to ascertain, by comparative, quantitative, practical tests, the characteristics of the various limes accessible to the Toledo market; but the precautions taken to secure samples of equal freshness proved insufficient, and the results were so far vitiated, that they could not be published in full, without injustice to some of the manufacturers who furnished the specimens for examination. I may mention, however, one general conclusion to which all the experiments tended. The "strength" of a lime, measured by the proportionate amount of sand with which it will make a coherent mortar, seems to be independent of the percentage of magnesia it contains.

The production of Lucas county, in 1869, was between 35,000 and 40,000 bushels.

Hydraulic Cement.—It is hoped that the Waterlime group will be found to afford beds suitable for hydraulic cement. Several samples that were selected for examination have been shown, by Dr. Wormley's analyses, to resemble the best cement rocks very closely in chemical composition, but the more practical and decisive tests are yet to be applied.

Glass Sand.—The friable sandstone of the Corniferous affords a nearly pure, white sand, adapted to the manufacture of glass. I am informed that in 1863 it was opened in Sylvania, on the farm now owned by Mr. John Rampus, by Messrs. Card and Hubbard, and a considerable quantity quarried, ground and washed, and shipped to Pittsburgh, Pa., where it was used in the manufacture of clear flint glass. Seven or eight hundred tons had been shipped, when the business terminated in consequence of the death of the managing partner, Mr. Card, and it has not been resumed. The price received for the sand, delivered in Pittsburgh, was $16 a $17 per ton. The accessible outcrop of the bed in Sylvania crosses sections 8, 17 and 20, and touches the north-east corner of section 7. It appears also in Monclova, at Fish's quarry, and on the Maumee near the east line of Providence.

Bog Iron Ore, in small amount, is found in nearly every depression of the sand district, and the existence of extensive accumulations in the

larger marshes is highly probable. Repeated attempts were made to examine some beds that have already been discovered, but the marsh was found too wet, and the consideration of the subject will have to be deferred.

Clay.—The stoneless lacustrine clay, which has an average depth of fifteen or twenty feet over the eastern part of the county, is well adapted to the manufacture of brick and tile, and sites are readily chosen, along the margin of the sand district, where the face of an excavation will give a proper proportion of sand and clay.

Gypsum, etc.—Some years ago announcement was made of the discovery of gypsum in digging for the foundation of a mill on Ten Mile creek, just below the village of Sylvania. The place is not now accessible, but I am led—by the statement of Mr. Warren of Sylvania, that he applied the substance in question to a portion of his garden without visible effect on the vegetation—to suppose that the announcement was premature. The locality, however, is below the middle of the Waterlime series, and not far above the horizon of the gypsum deposits in Ottawa county; and salt, the frequent associate of gypsum, is represented in the immediate neighborhood by pseudomorphous cavities after its hopper-shaped crystals. Calcite occurs in cavities of the arenaceous limestones of the Corniferous at Fish's quarry, and at Loeb's quarry. At the latter place it is associated with strontianite. At Waterville, calcite and petroleum are found together, in cavities within some rugose, calcareous concretions, often several feet in diameter, which abound in a stratum of argillaceous limestone of the Water-lime group, and are laid bare in the river bed.

Water.—The wells of Lucas county are of two classes, the shallow and the deep. The shallow pierce only the Lacustrine deposits, and receive either the water that accumulates in the deep sands of the oak openings, or that which percolates what sand-beds are interstratified with the Lacustrine clays; the deep wells penetrate nearly or quite to the rock. I am not aware that any wells draw water from the body of the Erie clay. Though it contains frequent permeable beds, they are not so connected as to permit a circulation.

At the base of the Erie clay, and resting on the rock *in situ*, there are commonly—but not always—found a few feet, or a few inches, of gravel and sand, from which water rises freely, supplying the artesian and other deep wells. Whether the water is confined to this horizon, or circulates also through the underlying rocks, is a question of little importance. If we say that it passes under the clay along the limestone ridge in the west part of the county, and follows the rock surface until it finds

escape upward, we shall have proposed a theory by no means demonstrable, but quite adequate to account for the artesian head at Toledo and in Oregon. The wells of Richfield township, of which one at least is artesian, deliver water considerably higher than this limestone ridge, and must receive their supply from some region further west, where the land is still higher.

In all the Toledo wells the water rises to about the same height, and it overflows only when the top of the well is below this common level or head. When there were but few wells, this head was fourteen feet above the river level; but with their multiplication, and the increasing consumption, it has been drawn down to seven feet, and the time cannot be distant when pumps will be required for the wells which now flow. The question which this opens of the limitations of the supply from this source is already recognized as of importance to Toledo, and a discussion of the conditions on which it depends will not be amiss, even though it be common-place, and leaves the practical question untouched. The water is commonly obtained from beds of sand, or gravel and sand, resting on the solid rock and covered by clay. We cannot regard these beds as strictly continuous, for we know that in some places the clay rests immediately on the rock, but we must suppose that they are connected over large areas, so that the water which circulates through them is essentially a broad sheet following the contour of the rock surface. At some elevated points (say, for example, the country from Sylvania to Whitehouse,) this sheet communicates with surface reservoirs and receives its supply, while at other, lower points, it is tapped, naturally or artificially, and discharges. There are probably natural outlets where the Maumee river has cut to the rock at Rock Bar, near Perrysburg, and at numerous points under the lake, where the rock is bared; but at Toledo the river has not worn through the clay. The friction afforded by the sand through which the water seeps must render the motion exceedingly slow, so that we may regard the Toledo wells as piercing a bed of sand, saturated with water under-pressure, which rushes in from every side to replace what is withdrawn. The amount that can be obtained at any one point is limited only by the friction of the water upon the sand, and this will vary with the local character and depth of the bed.

Manufactures.—The *Manhattan Iron Company*, J. B. B. Case, Superintendent, are engaged in the manufacture of pig-iron. Their site, on the Maumee, four miles below Toledo, combines shipping facilities with convenient access to the timber which furnishes the charcoal for their fuel. Their ore is brought from Lake Superior, and their flux from Kelley's

island, while their iron is chiefly shipped to Cleveland. The production, in 1869, was 1,634 tons.

Of bricks, the precise statistics are not readily collected, but the present annual production is not less than 12,500 m.

The manufacture of drain-tile has been commenced in Toledo and in Springfield, but has, as yet, attained no importance. The necessity of thorough drainage to the prosperity and health of the farmers of the Black Swamp district, cannot fail to be, in time, generally recognized, and the business of tile-making is destined to become an important industry.

The manufacture and use of *Artificial Sandstone* has recently been commenced in Toledo, and bids fair to continue and increase. The process used, known as the Frear patent, has been applied in Chicago for four years, and its best results are so good as to leave no doubt that artificial stone will henceforth hold place among our building materials. I by no means anticipate that it will supersede the use of natural stone. It has neither the beauty nor the strength (unless after many years of exposure), of the Amherst sandstone, for example, and cannot hope to supplant it, where elegance is the prime requisite; but its superior economy, as compared with cut stone, will recommend it for a great variety of external work, and especially ornamental work. As it is formed in molds, an ornamented surface can be produced almost as cheaply as a plain one; and any desired color can be given to the whole mass. When carefully and skillfully made, it has all the strength needed for ordinary architectural uses, and is so constituted as to become, like mortar, continually stronger with time and exposure.

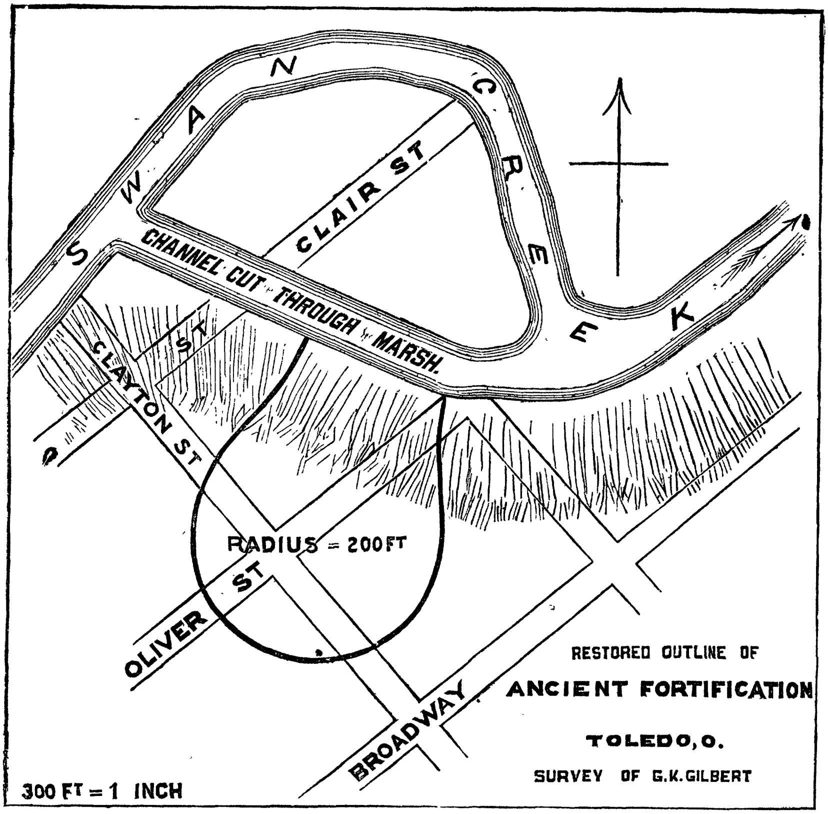
VEGETATION.

The broad distinction of "oak opening" and "timber," divides the vegetation of the deep sand, from that of the shallow sand and the clay soils. The peculiar, limited, arboreal flora of the former has already been described in the preceding chapter. The flora of the clay districts lying east of the sand, and forming part of the Black Swamp district, includes all the species enumerated as occurring in Williams county, with the exception of the tamarack, and, perhaps, the Kentucky coffee-tree. Among the most abundant are white elm, whitewood, linden, black and white ash, white and yellow oak, and sycamore. A few red cedars (*Juniperus Virginiana*, L.) cling to the river bluff at Roche de Boeuf.

ANTIQUITIES.

At Toledo are two small earthworks, in regard to which tradition is silent, and though it is questionable whether they belong to archæology or modern history, it is well to describe them before they are entirely destroyed. One is now intersected by Clayton and Oliver streets, and has been nearly obliterated by the grading, etc. It was pointed out to me my Mr. Charles A. Crane, an old resident, and from his description, and such fragmentary portions as remain, I have been able to restore the

Fig. E.



outline. It has the form of a semi-circle, 400 feet in diameter, resting on the bluff of Swan creek, down which the embankments were carried to the water. The second work is similar in form, and 387 feet in diameter. It is located on the east bluff of the Maumee, in Oregon township, just without the southern limit of Toledo; and the field which it traverses has never been disturbed by the plow. The ridge rises less

than two feet above the surface, and the ditches from which the earth was removed remain within and without. The curve is irregular, as though its location had been influenced by the position of trees, and at one point, probably the entrance, a second, short ridge lies inside the principal.

These and other facts have led to the conclusions—first, that the works are forts; second, that the embankments supported stockades; and, third, that they belonged to a people using the river, and protecting themselves against a foe in the forest. There is little to indicate their antiquity. Human bones (probably of Indians), with fragments of rude pottery, bones of fish, deer, &c., and excavated, kettle-shaped fire-places are found in close proximity to the eastern work, but their connection was not established. The other was based on a channel of Swan creek, doubtless then full of water, but at the commencement of the present occupation deserted by the stream, and filled to the condition of a marsh, through which a cut for navigation has recently been dredged.

A similar fort at Eagle Point, Wood county, described by Col. Charles Whittlesey, may be regarded as of the same series.

CHAPTER XXV.

GEOLOGY OF WEST SISTER ISLAND.

TOPOGRAPHY, ETC.

This island is situated eight miles north of Locust Point, Ottawa county, and twelve miles east of Cedar Point, Lucas county. It is rudely oval in form, with a longer diameter—in a north-east and south-east direction—of five-eighths of a mile, and a shorter of three-eighths; and is said to contain 104 acres. The north-eastern extremity presents a perpendicular bluff of twenty-five feet, and the height of the coast diminishes gradually to the opposite end, where the rock surface is at the level of Lake Erie. The entire shore of the island is of rock, excepting a narrow gravel beach, of eighty rods length, on the south side. From the eastern end of this beach a rocky bar extends a quarter of a mile in a south-easterly direction, under six feet of water, but on all other sides there is a rapid descent to a depth of thirty feet. Near the north-eastern end the land rises to a height of sixty or seventy feet.

The soil is a fertile black loam, in some parts gravelly, resting on the glacial detritus, coarse and fine, that covers the rock surface to the depth of a few feet. The Erie clay is apparently wanting. Snail shells, (chiefly *Helix albolabris*, Say) are so abundant as to form a conspicuous feature of the soil.

Glacial markings are well displayed at numerous points along the coast, and illustrate several interesting points, which have already been remarked in chapter XXI.

GEOLOGICAL STRUCTURE.

The dip of the rocks is mainly to the north-east, but there are many minor flexures, not recognized as systematic; at the south-western ex-

tremity the dip is south-west. The entire thickness of the exposed beds is ninety feet, as appears in the following descending section:

		Feet.	Inches.
1.	Soft, shaly limestone, yellowish brown, weathering to a gray; containing crystalline strontianite	2	......
2.	Pale, buff, brecciated limestone; at top thin-bedded, massive below	12	......
3.	Light drab limestone, fine-grained; with minute horizontal lenticular cavities, rarely containing calcite and selenite; beds 4 to 8 inches	8	......
4.	A darker, purplish, brecciated limestone; massive; containing numerous flint nodules, the largest 15 inches in diameter; upper surface irregularly mammilated	2	6
5.	Soft, buff, thin-bedded limestone	1	6
6.	Massive bed, like No. 4; the upper surface bearing low domes, one two feet across, not differing in appearance from the mass, but containing at center calcite or flint	2	......
7.	Compact, thin-bedded, crumbling, drab limestone	4	......
8.	A bed of soft, sparry, gypsiferous limestone, disappearing in a few rods	2	......
9.	Limestone, like No. 7	4	......
10.	Soft, drab, massive, highly gypsiferous limestone, changing in a few feet to one foot of sectile stone, resembling No. 11	3	......
11.	Hard, thin-bedded, crumbling, buff limestone, containing a little gypsum	1	......
12.	Bluish gray shale and shaly limestone	2	6
13.	Massive white gypsum, with some admixture of shale	3	......
14.	Soft, pale drab limestone	4	......
15.	A series of purplish drab limestone beds, alternately soft and massive (with some gypsum), and hard, compact and crumbling	13	......
16.	Drab limestone, minutely cellular	2	......
17.	Soft, argillaceous limestone, dark drab, weathering bluish gray, shaly toward the bottom	10	......
18.	Soft, pale buff limestone	3	6
19.	Pale, purplish buff limestone, in 4 to 10-inch beds, the surface of which present broad, convex undulations	10	......
	Total	90	0

A notable characteristic of many of the beds is a tendency to divide, by seams at all angles to the bedding, into small, irregular blocks, retaining their hardness. This is especially the case with Nos. 5, 7, 9 and 11, and the hard portions of No. 15, and in a less degree with Nos. 3, 4, 6, 14 and 17.

Though the age of these rocks is not shown by fossils, there can be little doubt that they represent portions of the Waterlime and Onondaga Salt groups of the New York System. The strontianite of bed No. 1, and the close resemblance of the brecciated limestone (No. 2) to a bed of known age on South Bass island, indicate that these are to be classed with the Waterlime; while the gypsum of beds 8, 10 and 13 claims for them a position in the Onondaga Salt group. Assuming No. 8 as the terminal member of the latter formation, we have in this section 32 feet of the Waterlime group, and 58 feet of the Onondaga Salt.

ECONOMIC GEOLOGY.

The bed of gypsum (No. 13) was seen to be continuous for several rods on the north shore, dipping with the adjacent beds to the north-east. By removing the soil its outcrop could readily be traced, and a considerable quantity removed at little expense. The same work would develop bed No. 10, which may at some point afford valuable masses of gypsum. The gypsum exposed in the escarpment is not sufficiently pure to warrant calcination, but is, nevertheless, valuable for agricultural purposes.

Several of the beds will furnish good wall stone, but the island affords no building stone likely to compete with that already in the neighboring markets. The same is, probably, true of the lime that may be burned here. Though no tests have been made, it seems probable that hydraulic cement will sometime be produced. Several beds, but especially Nos. 7 and 9, and portions of No. 15, have the appearance of hydraulic limestones.

REPORTS ON THE GEOLOGY

OF

SANDUSKY, SENECA, WYANDOT AND MARION COUNTIES.

BY N. H. WINCHELL.

PROF. J. S. NEWBERRY, *Chief Geologist:*

DEAR SIR:—I have the honor to transmit herewith reports on the Geology of Sandusky, Seneca, Wyandot and Marion counties.

Yours, very respectfully,

N. H. WINCHELL.

CHAPTER XXVI.

GEOLOGY OF SANDUSKY COUNTY.

SITUATION AND AREA.

Sandusky county has Ottawa on the north and Seneca on the south. It is bounded west by Wood and east by Erie. It contains twelve towns, or four hundred and thirty-two square miles. In its north-eastern corner it touches Sandusky Bay. Its greatest dimension is east and west thirty miles. Its form is that of a rectangular parallelogram.

NATURAL DRAINAGE.

The Sandusky river, which intersects it about midway in a direction a little east of north, and enters Sandusky Bay in Riley township, is the chief river of the county, and is navigable to Fremont by reason of slack water from the bay. Below Fremont the immediate river channel is crooked, and the stream widens out into bayous, covering considerable low land. Above Fremont its course is more direct, and it lies almost constantly on the rock, which offers abundant exposure, to the south line of the county. The Portage river also crosses the north-west corner of the county, passing through Woodville township and village. Besides these, which may be relied on for a constant flow of water, even in the driest seasons, there are numerous creeks, whose direction is also north-easterly. Some of these are also constant-flowing streams, but the most of them cannot be depended on for water-power purposes. Such are Sugar creek, Big Mudd creek, Muskalunge creek, Green creek, and Raccoon creek. Wolf creek, also, which enters the Sandusky from the south-west in Ballville township, drains a considerable tract of country, and has a constant current. Of these, the Green creek, whose chief supply is the sulphureted water from the mineral springs in Green-creek township, is a constant stream, and at the present time affords power for several mills.

SURFACE FEATURES.

With the exception of the township of York, and small parts of Townsend and Greencreek, in the eastern portion of the county, the surface is generally a monotonous plain. Being included in that tract long and well known as the Black Swamp, its features to many persons are best expressed by giving it that title. As in Ottawa county, the limestone ridges, sometimes capped with lacustrine sand, are the only observable changes of level. They are more frequent, especially in the western part, than in that county, and sometimes a number of fields are so stony, or the rock is so near the surface, that the land is used only for pasturage. Their height, with the addition of the sand deposit, sometimes amounts to twenty-five or thirty feet; but the ascent is very gradual, and distributed often over half a mile. In Scott township, in the south-western part of the county, there are patches of natural prairie. These are due to imperfect natural drainage. The undulations in the surface of the Niagara limestone, over which they occur, operated, by the aid of the drift, to confine shallow pools of water upon the retirement of the lake. Usually the low, continuous, rocky rim can be detected jutting a few inches or feet above the surface, or sometimes rising in the form of conspicuous ridges. Such shallow pools would eventually become marshes, where vegetable deposits would accumulate, and at last, when the surrounding country had become forest-covered, they would appear as prairies. It is a common coincidence in the Black Swamp that the most stony tracts are also the wettest. Had the original drift been undisturbed by the waves of the lake, such confined pools would have been likely to work out for themselves some escape through the more erosible materials, and to have become clothed sooner with the indigenous forest.

The valleys of the streams are worn in the drift. That of the Sandusky is fifty-three feet, to the water level, at Fremont—sixty-five to the bed of the river. At Ballville the river is running on the rock, and its surface is forty-seven feet five inches below the general level. Its banks, consisting of the stiff hardpan, or sometimes superficially laminated, are abrupt, and very often steep, although one or the other is frequently from fifty to one hundred rods from the channel of the river. The height of the flood-plain varies in accordance with the obstructions to the current, but at Fremont it is but four and a half feet above the level of slack-water. This, however, cannot express the average height of the flood-plain, but rather shows the rise of Lake Erie under the influence of spring freshets. Below Fremont, the valley of the river is broader, and the accumulated waters have freer escape. Above that point the flood-plain

sometimes rises ten and twelve feet above summer stage of the river. Bordering and enclosing the flood-plain, the drift banks rise from thirty to forty feet, and constitute by far the most noticeable changes of level to be seen in the county. These banks are not confined to the larger streams, but seem to be as deeply cut along some of the creeks as along the Sandusky river. In traveling the "river road," one cannot but be struck with the frequency and depth of the tributary valleys. These little valleys are often occupied by streams only in the spring and fall of the year, but the moist and loose state of the drift at those seasons combines with the activity of the current to wash out their valleys as deep as that of the main stream.

In the south-eastern portion of the county the surface contour is quite rolling, and in the monotony of the general aspect elsewhere, might be styled picturesque. For a full discussion of the causes and changes that introduced this rolling, sandy tract, in Sandusky county, the reader may consult a preceding chapter on the drift in north-western Ohio.

SOIL AND TIMBER.

The soil is clay, with a little gravel, being the old drift surface, and has a depth corresponding to the thickness of that deposit. Local circumstances have added accidental qualities in various parts of the county. In localities, poorly drained by the natural conformation of the surface, considerable addition of partially decayed vegetable remains has given it a peaty composition, and a black color. Places subject to erosion have become gravelly or even stony, the fine constituents of the drift having been washed out, while the action of the waves of Lake Erie, over much of the county, has served to heap up isolated sandy knolls and to deposit a heavy accumulation of sand in the south-eastern part of the county. While the soil of the whole county is fertile and adapted to all farm products, the warmth and quickness of the sandy soils, in the townships of Townsend, York and Greencreek, united with a pleasant, undulating surface, and the ease of drainage, have given the lands of these townships for the time being an enhanced market valuation. When, however, the county becomes more perfectly subjected to artificial drainage, the clay soils will remain the chief source of agricultural wealth, when perhaps the lighter soils have become exhausted. The most of the county was originally covered with low-land varieties of timber. Elm, hickory, cottonwood, beech, ash, the various species of oak, maple, with some black walnut and honey locust, may be seen in traveling over the county. In a few places trees of pepperidge and of chestnut were also seen. Much of the sandy tract in the south-eastern part of the county was known among the early settlers as "oak openings."

GEOLOGICAL STRUCTURE.

The rocks underlying the county belong to the Upper Silurian and Devonian ages, the highest being the Corniferous. They embrace—

Upper Corniferous limestone		Devonian.
Lower Corniferous limestone		
Oriskany sandstone		
Water limestone		Upper Silurian.
Salina shale		
Niagara limestone		

The *Niagara* occupies two belts of anticlinal outcrop across the county north and south. The boundaries of the eastern belt are not certainly known, and the map of the county is to be regarded as conjectural throughout the most of that area. The outcropping edges of the western belt have, however, been carefully traced across the county, owing to the frequent exposures of water-worn surfaces which there occur. The western boundary of the western belt enters the county from the north in Sec. 8, Woodville, and runs nearly south, gradually approaching the county line, which it crosses in Sec. 6 in the same township. The eastern boundary of this belt enters the county, N.E. ¼ Sec. 27, Washington township, in a south-easterly direction, which it keeps for about four miles, when it turns to the south and south-west, again south, leaving Washington township, S.E. ¼ section 34. It keeps a southerly course, crossing the Lake Erie and Louisville railroad a mile north of Winter Station, nearly to the ocunty line, when it is suddenly diverted eastward, and leaves the county, S.E. ¼ Sec. 31, Ballville township. The only exposures of the east belt of outcrop are at Fremont, where it can be seen below the dam near the railroad bridge, and at Moore's mill dam, near Ballville. These are on the western border of the belt, which has a width of about six miles. The western portions of the townships of Riley and Greencreek, and the eastern portions of Rice, Sandusky and Ballville, are probably underlain by the Niagara.

In the western part of the county, where the drift has been considerably eroded by the action of the waves of Lake Erie, the rock is very often laid bare. The following list of outcrops, which is probably far from complete, will give some idea of the denudation that has taken place. There is, however, no evidence of a beach line where the shore of the lake stood stationary. The shore line seems rather to have begun at once a

slow recession. In the township of Woodville the following were noted, not including those in the bed of the Portage:

N.W. ¼ Sec. 22. This ridge runs several miles easterly, rising also on the south side of the Portage. At Woodville it is capped with sand.

N.W. ¼ Sec. 9. This ridge runs to Genoa, in Ottawa county, and is known as *Trimmer's Ridge.*

S.W. ¼ Sec. 35. Considerable surface exposure of gray and crystalline Niagara.

S.W. ¼ Sec. 36. Thick-bedded, crystalline Niagara, affording a fine building stone.

S.W. ¼ Sec. 5. Ridge of Niagara, running north and south, showing characteristic Niagara fossils, on the land of Jacob Sanders, and others.

S.W. ¼ Sec. 6. Land of John Caler. This ridge has been excavated for a cellar, and the stone is a very light drab, weathering buff. It is porous, and often carious, in rough and irregular, also in even, beds; the even beds are sometimes a foot thick. Under the weather it often crumbles much like chalk. The ridge holds a deposit of sand.

IN MADISON TOWNSHIP.

S.E. ¼ Sec. 27. Niagara ridge crosses the road.

S.W. ¼ Sec. 34. Niagara ridge.

S.E. ¼ Sec. 34. Niagara ridge.

Sec. 35. On the town line.

S.W. ¼ Sec. 10. At the crossing of the creek.

S.W. ¼ Sec. 7. Land of A. J. Nolan. Rock similar to that in Caler's ridge, S.W. ¼ Sec. 6, in Woodville township.

IN WASHINGTON TOWNSHIP.

N.W. ¼ Sec. 32. A low ridge of Niagara; is worked a little near Lindsay for foundations to farmers' houses, on land of Mr. Behring, and of Mr. Hagerman.

S.W. ¼ Sec. 3.

N.E. ¼ Sec. 10. In the bed of Big Mudd creek; dip E. about 4°.

S.E. ¼ Sec. 11. Near the railroad crossing of the highway; dip apparently east.

N.W. ¼ Sec. 11. Under the railroad bridge.

N.E. ¼ Sec. 8. Crossing of Nine-mile creek.

S.E. ¼ Sec. 20.

S.W. ¼ Sec. 17.

S.W. ¼ Sec. 14. A ridge running east and west, rising about fifteen feet.

S.E. ¼ Sec. 29. Niagara ridge.

Sec. 32. At two points half a mile separate, in ditches by the roadside.

IN BALLVILLE TOWNSHIP.

S.E. ¼ Sec. 31. J. Bruner quarries the Niagara; dip east.

S.W. ¼ Sec. 31. Land of Amos Mull. In the bed of the creek.

IN SCOTT TOWNSHIP.

S.W. ¼ Sec. 4. Land of William Boor. Ridge runs nearly north and south.

S.E. ¼ Sec. 4. Ridge of Niagara on John Houtz's land; Peter Rust also has land on this ridge.

N.W. ¼ Sec. 9. Land of Daniel Shively.

N.E. ¼ Sec. 9. Much stony land.

Secs. 31 and 30. "Stony Barter."
Sec. 3.
Secs. 17 and 16.
Sec. 28.
} In the midst of prairie.

IN JACKSON TOWNSHIP.

N.E. ¼ Sec. 4. Ridge of Niagara, half a mile east and west.

S.W. ¼ Sec. 3. Niagara in a field; dip E.

S.W. ¼ Sec. 4. In a ditch by the roadside.

S.E. ¼ Sec. 3. On the farm of Mr. Burkett.

S.E. ¼ Sec. 15. Prominent ridge.

S.E. ¼ Sec. 27. Ridge crosses the road.

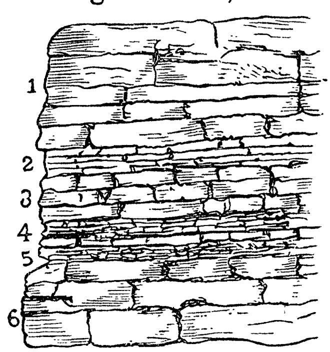
N.E. ¼ Sec. 34. As a ridge.

S.E. ¼ Sec. 35. In the creek, land of Riley Betts.

S.W. ¼ Sec. 35. In the west branch of Wolf creek, within thirty rods of the county line road, the Niagara is seen dipping west at an angle of eight degrees, exposed about two feet. It is overlain by Waterlime containing *Leperditia alta*, in thick, rough beds, showing two feet and three inches, followed by about a foot of shattered, thin beds. The Waterlime seems here to lie conformably over the Niagara, and dips with it toward the west.

The section at Moore's mill, near Ballville, exposes the superposition of the Waterlime and Salina over the Niagara.

Section including the Salina, at Moore's Mill.



EXPLANATION OF FIGURE.

No. 1.	Thick-bedded, drab, used for building	6 ft. 6 in.	Waterlime, 15 feet.
No. 2.	Thinner-bedded, drab, more sectile, weathers lighter	1 ft.	
No. 3.	Beds about six inches, drab, used for building	3 ft.	
No. 4.	Beds three to six inches, drab	4 ft. 6 in.	
No. 5.	Green shale, passing horizontally into an impure, bluish-drab stone	1 ft.	
No. 6.	Bluish-gray Niagara; beds thick, hard and crystalline, exposed	3 ft.	

The Waterlime immediately overlying the shale, contains the characteristic fossil *Leperditia alta.* The Salina shale (No. 5) appears in patches, gradually becoming a rather firm and blue stone. Sometimes irregular beds of fragile, earthy limestone appear within the shale, projecting conspicuously after the shale has crumbled out. On exposure to the air, the shale turns blue and crumbles. Its deposition seems sometimes to have been distributed through the first few feet of the Waterlime above, instead of being concentrated in a single bed. In such cases the Waterlime is blue-drab near the base, and if porous and crystalline, it is with difficulty distinguished from the Niagara. No. 6 is in the bed of the river, and crosses it just below the dam, the water falling upon it. It lies as an anticlinal with axis N. W. and S. E., rising toward the N. W. and producing an upward swell in the overlying drab beds. The section below the railroad bridge, at Fremont, cannot be made out with certainty, owing to the prevalence of the water. Five feet and five inches can be seen of gray, crystalline Niagara, in beds of eighteen to twenty-eight inches. Overlying this, but below the water of the river, are about two feet of earthy, drab Waterlime in beds from two to six inches. The Salina, if it exists here, cannot be seen. The whole dips six to eight degrees south, ten degrees east. It formerly rose considerably above the bank, along the road near the railroad bridge over the highway, and was quarried there for walls and abutments, the stone for the railroad bridges having been obtained there.

The Guelph phase of the Niagara, which appears at Genoa, in Ottawa county, is met with only in the western part of Sandusky county, and near the Wood county line. The Niagara is usually a hard, thick-bedded, crystalline rock, which, although requiring considerable labor in quarrying, furnishes, whenever systematically and persistently worked, an excellent and valuable stone for building. It must be admitted, however, that the formation has not been sufficiently opened, within the limits of the county, to prove the non-existence of the Guelph in other portions.

The *Salina Shale,* which immediately overlies the Niagara, has been

seen at but one point in the county. As already mentioned, it has a thickness of one foot at Moore's mill, but further north it was penetrated by drilling, according to Mr. G. G. Tindall, of Fremont, a thickness of eleven feet before the drill struck the Niagara. It perhaps underlies the eastern part of Riley and the northern portion of Townsend townships, for it certainly has a greater thickness toward the north. Sandusky bay is doubtless an excavation, to a large extent, in the Salina shale.

The Water Limestone occupies that portion of the county west of the western belt of Niagara, the strip included between the two Niagara areas, which lies west of Fremont, and includes the most of the townships of Ballville, Sandusky and Rice, and portions of Jackson and Washington, together with an area not distinctly defined, crossing the eastern part of the county through Greencreek and Townsend townships. This formation appears very much as it does in Ottawa county, and presents the three different lithological phases. The frequency of its exposures in the western portion of the county is equal to that of the Niagara. The "limestone ridges" which it causes are very often covered with sand which lies in hummocky contour. Its most important exposures are at Fremont, where the ridge it there produces has been extensively wrought for lime, and for general use in walls and rough paving; and at Ballville, where the river has excavated a channel through it, so as to expose upward of thirty feet of bedding. Aside from these, which will be separately described, the Waterlime was seen in outcrop in the following places:

IN WOODVILLE TOWNSHIP.

N.W. ¼ Sec. 31. Land of D. H. Rex; thick-bedded soft Waterlime, furnishing a good building stone; dip S. W. 4 degrees. This ridge runs north, ten degrees east, and is about two miles long.

Sec. 6. Near the county line, in the Portage; also half a mile east.

N.W. ¼ Sec. 32. Thick-bedded, drab; in the bank of the Portage, ten feet above the water.

IN WASHINGTON TOWNSHIP.

N.E. ¼ Sec. 25. Near the Ottawa county line, the *Ruhl ridge*, consisting of brecciated Waterlime, rises about six feet.

N.W. ¼ Sec. 23. Waterlime which contains the fossil *Leperditia alta*.

S.W. ¼ Sec. 14. Even-bedded Waterlime dipping N. E. within fifty rods of gray Niagara limestone, which forms a ridge running E. and W., and rising about fifteen feet. The Niagara lies west of the Waterlime, and between them are several clumps of brecciated Waterlime showing *Leperditia alta*.

N.E. ¼ Sec. 27. Waterlime ridge east and west, with a deposit of sand.

S.W. ¼ Sec. 36. In a ditch by the roadside; also in a field adjoining.

N.E. ¼ Sec. 13.

IN JACKSON TOWNSHIP.

N.E. ¼ Sec. 10. Fragile beds of soft Waterlime have been used for the "Greensburg pike." Beds horizontal so far as discernible, the quarry being in low ground and filled with water.

N.E. ¼ Sec. 11. Sandy knolls, which probably lie on Waterlime.

S.W. ¼ Sec. 2. Intersection of the "Greensburg pike" and Muskalunge creek.

S.W. ¼ Sec. 35. In thick, rough beds, overlying the Niagara, and followed by a foot of thin beds.

N.E. ¼ Sec. 35. In the N. Branch of Wolf creek.

IN BALLVILLE TOWNSHIP.

S.E. ¼ Sec. 6. This ridge is remarkably overstrewn with northern bowlders.

S.E. ¼ Sec. 19. In the road, joining James Wickard's land; also on John Halter's land in the bed of the creek.

S.W. ¼ Sec. 30. Near a steam sawmill, in the W. Branch of Wolf creek.

N.W. corner Sec. 31. Land of D. Mull, in the bed of the creek.

N.W. ¼ Sec. 29. From this place to Ballville the Sandusky river lies immediately on the Waterlime.

IN SANDUSKY TOWNSHIP.

S.E. ¼ Sec. 32. Burned for lime.

N.E. ¼ Sec. 32. Burned for lime.

S.E. ¼ Sec. 19. At the Four-mile house; furnishes some large, rough blocks for walls and abutments.

About half a mile west of the depot, at Fremont, the Waterlime is extensively burned into lime. Quarries have been opened by D. L. June, Daniel Quilter, Philip Gottern, and by others. The stone disclosed in these quarries is a light drab, usually thin-bedded stone, close textured and even flinty in some parts. Mr. June has penetrated, in his quarry, through the Salina, and entered the Niagara. The openings were at first made in the summits of gentle anticlinals, the rock dipping, as it is exposed on working deeper, in opposite directions. This is the case with the three principal openings, viz.: those of June, Quilter and Gottern. The following section, from Mr. June's quarry, may be taken as a fair illustration of all of them:

Downward Section of the Waterlime at Fremont, including the Salina, and the upper part of the Niagara.

No. 1. Beds two to four inches, separated by bituminous films, generally close-grained, but sometimes vesicular and crystalline; disturbed with nodules and thin beds of chert.................................... 10 ft. 6 in.

No. 2. Beds two to six inches, more even and with less chert, the mammilated surfaces separated by bituminous films; used for flagging... 9 ft.

No. 3. The same as the last, or changing horizontally to a thick-bedded or massive, softer stone, exhibiting the lithological characters of phase No. 2. The bedding here is sometimes disturbed by dome-shaped or concretionary masses; useful for paving and general building, and as a cut stone.. 2 ft. 6 in.

No. 4. Salina shale; in some places wanting; or replaced by a thin film of bituminous matter, with some harder and more rock-like beds..... 6 to 12 in.

No. 5. Gray, thick-bedded, non-fossiliferous, vesicular Niagara, with some galena exposed .... 3 ft.

The dip in Mr. June's quarry is S. W. and N. E., at angles of fifteen to twenty degrees, in opposite directions. Mr. Quilter's quarry is about 180 rods south-west from Mr. June's, and the rock, which is apparently on the same horizon, also dips S. W. and N. E. with about the same angles. Mr. Gottern's quarry, about sixty rods south of Mr. Quilter's, has an east and west anticlinal axis, the dip being about ten degrees in either direction. A little to the south-west of Mr. June's quarry, and between it and Mr. Quilter's, may be seen a number of clumps of rough, cavernous, brecciated Waterlime, which must overlie all the rock of the quarry, and doubtless corresponds to the upper part of the exposure in the Sandusky river, at Ballville, which is as follows:

Downward Section of the Waterlime at Ballville, below the bridge.

No. 1. Thick-bedded (2 to 3 feet), porous, rough and crystalline, or massive and brecciated, of a drab color.. 8 to 10 ft.

No. 2. Thin-bedded, drab, with streaks of darker color and more compact texture, occupying the bed of the river, and rising a few feet above the water along the south bank. This member is filled with curious concentric, ellipsoidal laminations; exposed.................... 6 ft.

Between Ballville and Moore's Mill, half a mile up the river, the formation is nearly horizontal, or has a slight dip to the east, but shows such local flexures, whenever visible, that no reliance can be placed on the dip in correlating the outcrops. Judging, however, by the lithological characters, the outcrop at Fremont may be united with those in the Sandusky river, so as to produce the following general section of the lower part of the Waterlime:

General Section of the lower part of the Waterlime in Sandusky County, in descending order.

No. 1. Massive, or thick-bedded, often brecciated, exposed between June's and Quilter's quarries at Fremont, and in the left bank of the Sandusky river just below Moore's mill. (No. 1 of the section at Ballville). Phase No. 1........................ ....10 to 15 ft.

No. 2. Thin-bedded, drab, cherty, with bituminous films, (Nos. 1 and 2, at June's quarry). Phase No. 3. Generally close grained. The lower portion of this sometimes, as at June's, passes into thick beds of a softer and coarser texture, when it has the features of phase No. 2 .... 25 feet.

THE ORISKANY SANDSTONE.

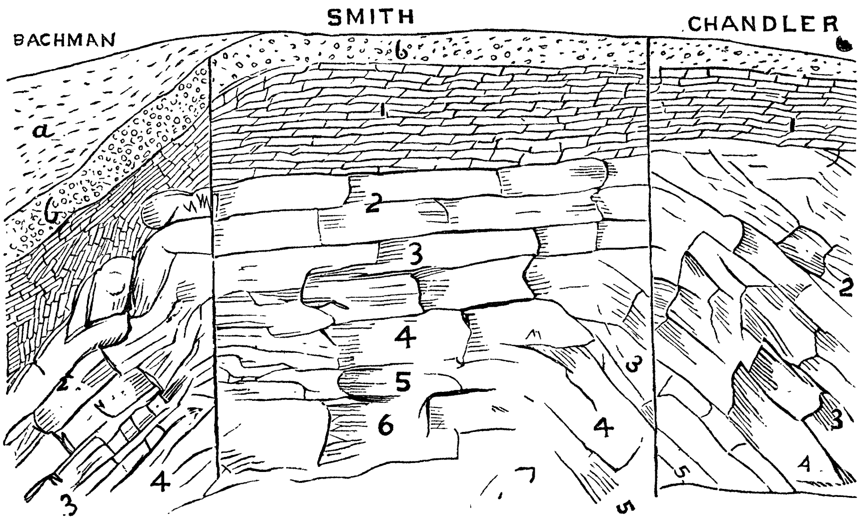
This is represented in Sandusky county by thin arenaceous layers at the base of the quarries of Messrs. Smith, Bachman and Chandler at Bellevue, (see sections of these quarries, p. 604). On fresh fracture it is a handsome blue, or mottled with drab and blue. In other counties this sandstone is ten or fifteen feet thick, but here it is not over two. Its only use heretofore has been for macadamizing roads, for which it is admirably adapted. Yet recently Mr. Smith has succeeded in making a waterlime cement from this stone, the sand contained within the mass answering for that usually mixed with the cement by the masons. The individual grains of sand are quite distinct, and often large enough to be called gravel. The larger are from a half to three-fourths of an inch across, and have much the aspect of fragments of earthy, close-grained, drab limestone, others are cherty or silicious, and pass into quartzite. These larger pieces are, however, very rare, the mass being a homogeneous sand in rounded grains.

This sandstone is overlain by six feet of the Waterlime formation, or at least by that amount of thick-bedded, drab limestone, with wavy bituminous films, and all the lithological characters of the Waterlime. Hence it seems that the Oriskany, or at least the sandy phase which is here supposed to represent the Oriskany, is not always in the same stratigraphical horizon. This fact is more fully confirmed by observations made in Wood and Paulding counties.

CORNIFEROUS LIMESTONE.

The Corniferous limestone is next higher in the geological series. It is separated into two parts, the *Upper* and the *Lower*, which are not only stratigraphically, but also lithologically distinct. The Lower Corniferous comprises the greater part of the rock exposed in the quarries of Messrs. Bachman and Chandler, at Bellevue, and the upper portion of Mr. Smith's at the same place. Mr. Emery Farnsworth also has opened a quarry in the same, near that of Mr. Chandler. The Upper Corniferous is seen in the quarry, now abandoned, within the corporate limits of Bellevue, as well as in Mr. Samuel Huffman's, N.E ¼ Sec. 25, York township, and in Mr. John Stetler's N.E. ¼ Sec. 34. The former is a buff-

colored, rather coarse-grained, magnesian limestone, rough to the feel, and often disturbed by irregular nodules or almost continuous beds of chert. The latter is a bluish gray, crystalline, hard stone, in even beds, which are usually conspicuously fossiliferous. This formation underlies the most of York township, and the south-eastern part of Townsend. It produces a more elevated tract of country wherever it occurs in north-western Ohio; and in Sandusky county, in connection with the St. Lawrence glacier, and the subsequent action of the shore line of Lake Erie, has given to the townships of York and Townsend the topographical and agricultural features which are in so marked a contrast with the rest of the county. Approaching from the south-west across the State, several of the ridges converge toward Bellevue. West from Bellevue the surface descends, and it is only at points considerably further south that the same altitude is reached. Hence the "lacustrine region" rapidly widens toward the west, just as the glacier was also more easily prolonged in that direction than in any other. The shattered condition of the rock in the quarries at Bellevue, and in Thompson township, Seneca county, attests the violence of that force which last acted on them, and indicates that the Corniferous limestone was the pivot on which the glacier swung in emerging from the rocky barriers that confined it further east along the Lake Erie shore.



Corniferous, Oriskany, and Water Lime, Bellevue.

The above section, which includes the adjoining quarries of Lyman Chandler, James F. Smith and Jacob Bachman, at Bellevue, while it

shows the disturbed condition of the formation at that point, also is interesting because it is the only place in the county where the relations of the Waterlime, Oriskany and Corniferous can be seen. This whole section is remarkably shattered, and the layers to the depth of thirty feet are thrown down from their natural position eight or ten feet, sometimes lying nearly on their edges.

EXPLANATION OF FIGURE.

Drift.	*a.* Fine sand in a massive bank; without stratification, containing the sticks and bark of White Birch	12 ft.
	b. Unassorted, gravelly drift	4 ft.
No. 1.	Beds two to four inches; buff; rough; magnesian; unfossiliferous: with continuous beds of chert	8 ft.
No. 2.	Magnesian and rough, with some sand, especially in the lower part; buff; beds 24 to 40 inches	10 ft.
No. 3.	Dark drab; striped with wavy and bituminous films; soft when weathered; harder and somewhat blue below; mainly in two beds	3 ft.
No. 4.	Dark drab; dense so as not to weather or bleach white; its upper six inches are much lighter, and earthy-magnesian; separated from No. 3 by a thick, constant, bituminous film. Below it becomes arenaceous, and is of a light blue on deep fracture, which, however, soon fades, turning a grayish buff with rusty films and streaks; in one bed	3 ft.?
No. 5.	Sandstone, of a handsome blue color, like the lower part of No. 4. Beds of about two inches, separated by thick bituminous films; rather fragile	1 ft.
No. 6.	In thick beds, or massive; often rough, porous and crystalline. On fracture of a massive bed, the section shows a wavy and curly, internal stratification, with alternating strips of lighter and darker drab; contains large masses of coarse crystals of calcite, and indistinct impressions of *Leperditia alta*. Exposed	4 ft.

It will be noticed that besides the arenaceous layer No. 5, there is also considerable sand in No. 2. Although this holds the place the Oriskany ought to have, viz: the base of the Corniferous, it is more likely to be represented, as already stated, by No. 5.

In Mr. Smith's quarry, No. 3 is more bleached, appearing in that condition more brittle, and fracturing somewhat like chalk, although much harder. When thus broken the bituminous films appear as rusty, wavy marks across the section. It is one of the most prized portions of the quarry, both for the whiteness of the lime it makes, (hence is distinguished by the workmen as "The White Stone,") and for the thick, even blocks it affords for walls and general building.

The *Upper Corniferous* is a hard, gray, crystalline stone, which has a thickness of something over forty feet, and contains interesting fossil

remains. Its regular bedding easily separates into flagging, or is broken into stone useful for all building. It is used for both purposes, and from Sandusky, in Erie county, it is extensively exported to distant points.

THE DRIFT.

This deposit covers the whole county with a nearly uniform spreading. No reliable actual measurements of its thickness have been made in the county, but its average thickness would probably not exceed one hundred feet. It seems to be somewhat thicker in the eastern half of the county than the western, owing to denudation by the old lake shore over the area of the Niagara limestone. It is usually a typical, unassorted and unstratified glacial deposit or hard-pan. Occasional places of oblique stratification may be referred to the action of water issuing from the glacier, and do not affect the general glacial origin and non-stratified condition of the great mass. The stratification of the drift exhibited in the banks of the Sandusky river, at Fremont, is confined to the upper twenty or thirty feet. The character of its junction with the unstratified hard-pan below, seems to indicate the presence of the glacier at the time the stratification was forming, or at least at the time of its commencement. It is probably due to running water, and may be assigned to the action of the Sandusky river, which, being set back by the retreating foot of the glacier, would spread over a considerable lateral surface. This would necessitate the flow of the Sandusky considerably above its present level. It may be referred, perhaps, with more reason, to the effect of water issuing from the glacier, and spreading uniformly over the surface along its retreating foot, depositing a stratified material free from gravel and stones, owing to the distribution of its current over a wide, shallow valley. This would also account for the occurrence of similar laminations at points, removed from the Sandusky river, and where they cannot be ascribed to the effect of any stream at present existing.

MATERIAL RESOURCES.

Being mostly included in that area known as the Black Swamp, Sandusky county has an inexhaustible store of wealth in the strong and deep soil so characteristic of that tract. The industries of the people are mainly agricultural. Nevertheless the development of the resources embraced in the underlying formations has not been neglected. The Niagara limestone has been opened in a number of places in the western part of the county, and has been found to supply a stone equal, in every respect, for purposes of building, to the famous Dayton stone, of southern

Ohio. If an effort were made to introduce this stone into the markets of Toledo and Detroit, owing to cheaper transportation, it would probably exclude those distant quarries from the northern trade. At the present time but little more is done than to meet the local demand.

The quicklime made from the quarries of Messrs. June, Quilter and Gottern, in the Waterlime formation at Fremont, has a wide reputation and sale, particularly in eastern cities. It is extensively shipped to Pittsburg, Pa., for use in the manufacture of glass. It also goes as far as Philadelphia and Boston. This lime furnishes more nearly the qualities of the Waterlime, when used for this purpose, than the quarries in the same stone at Genoa, in Ottawa county, and it will probably better answer the description there given, and more exactly bear out the comparison to the Niagara, than that burned at Genoa. It is not a pure white, but has a faint tint of yellow. It requires, however, to be seen in bulk to render the yellow tint discernible.

The following list of lime-burners, with the annexed columns, will show the comparative qualities of the Niagara, Waterlime and Corniferous, in their adaptation to the manufacture of quicklime. This list is made out from the statements of the proprietors themselves, or their foremen, and is as nearly correct as can be made without extensive trials and comparisons :

Name of Firm.	Location.	Formation.	Cords of wood per 100 bushels.	Weight per bushel of bulk.
				lbs.
D. L. June and Son	Fremont, Sandusky Co.	Waterlime	1	75
Daniel Quilter	Fremont, Sandusky Co.	Waterlime	$2\frac{1}{2}$	75
Phillip Gottern	Fremont, Sandusky Co.	Waterlime	$2\frac{1}{2}$	75
Wyman and Gregg	Genoa, Ottawa Co	Waterlime	2	70
Newman and Ford	Genoa, Ottawa Co	Waterlime	......	70
Frank Holt	Genoa, Ottawa Co	Niagara	$1\frac{3}{4}$	......
Lyman Chandler	Bellevue, Sandusky Co.	L. Corniferous and Waterlime	$1\frac{1}{2}$–2	75
James F. Smith	Bellevue, Sandusky Co.	L. Corniferous and Waterlime	$1\frac{1}{4}$	70
Delzal and Overmeyer	Lima, Allen Co	Waterlime	2 1-7	......
Thomas Cook	Harper, Logan Co	L. Corniferous	2 2-5	......
Benj. M. Fisher	Celina, Mercer Co	Niagara	3	......

It will be seen that the amount of wood used by different firms varies considerably, even with the same stone, quarried at the same place. This is owing to the difference of construction of the kilns. Mr. June, for instance, at Fremont, burns one of the most compact and difficult kinds of stone, yet, by the use of a peculiar kiln, he consumes less than

one-half the wood burned by Mr. Quilter or Mr. Gottern. Most of the kilns used in north-western Ohio are of the old style, and once filled and burned, have to be emptied and allowed to cool before more lime can be made. Some have constructed an improved style of kiln, which runs uninterruptedly, thus avoiding the loss of time and heat incident to the old style; but so far as observed, Messrs. June and Son, of Fremont, produce a more evenly burned lime, and with less wood, by using Page's patent draw-kiln.

The lime made from the Lower Corniferous by Mr. Lyman Chandler, of Bellevue, is so mixed in the process with the Waterlime layers below, that its character cannot be certainly stated. It is found, however, to be a very strong lime, although not a pure white. Some of it is greenish-gray; some of it yellowish or buff, like the stone before burning, and much of it is a light ash-color.

In Sandusky county there is no difficulty in obtaining stone for all common uses, in abutments, foundations and walls. Besides the abundant outcropping in the western part of the county, the quarries at Bellevue and Fremont supply the demand in the eastern portion, and considerable is also sent into adjoining towns. The stone and lime forwarded per the Lake Shore and Michigan Southern railroad, in 1870, from Fremont, was 6,401,092 pounds; from Bellevue, 1,215,304 pounds.

For brick and tile, and for pottery, the surface clay, particularly where it is finely laminated with sand, as at Fremont, is well adapted in all parts of the county. An excellent quality of brick is made at Fremont, by puddling these materials closely, the sand furnishing the sharpness and the strength needed, as well as preventing the tendency to warp and crack where clay alone is used. The following list embraces all, or nearly all the establishments of this kind within the county:

AT FREMONT.

O. T. Ball....................Brick.
William Mayford....................Brick.
Charles Giesen....................Brick.
Tistler & Rechtenwaldt....................Brick.
William Parker....................Brick and tile.

AT CLYDE.

Dirlam & Dewey....................Brick.

AT BELLEVUE.

Mr. Gale....................Brick.

AT LINDSAY.

Daniel Monk....................Brick.

AT GREENSPRING.

———— ? ....Brick.

WELLS AND SPRINGS.

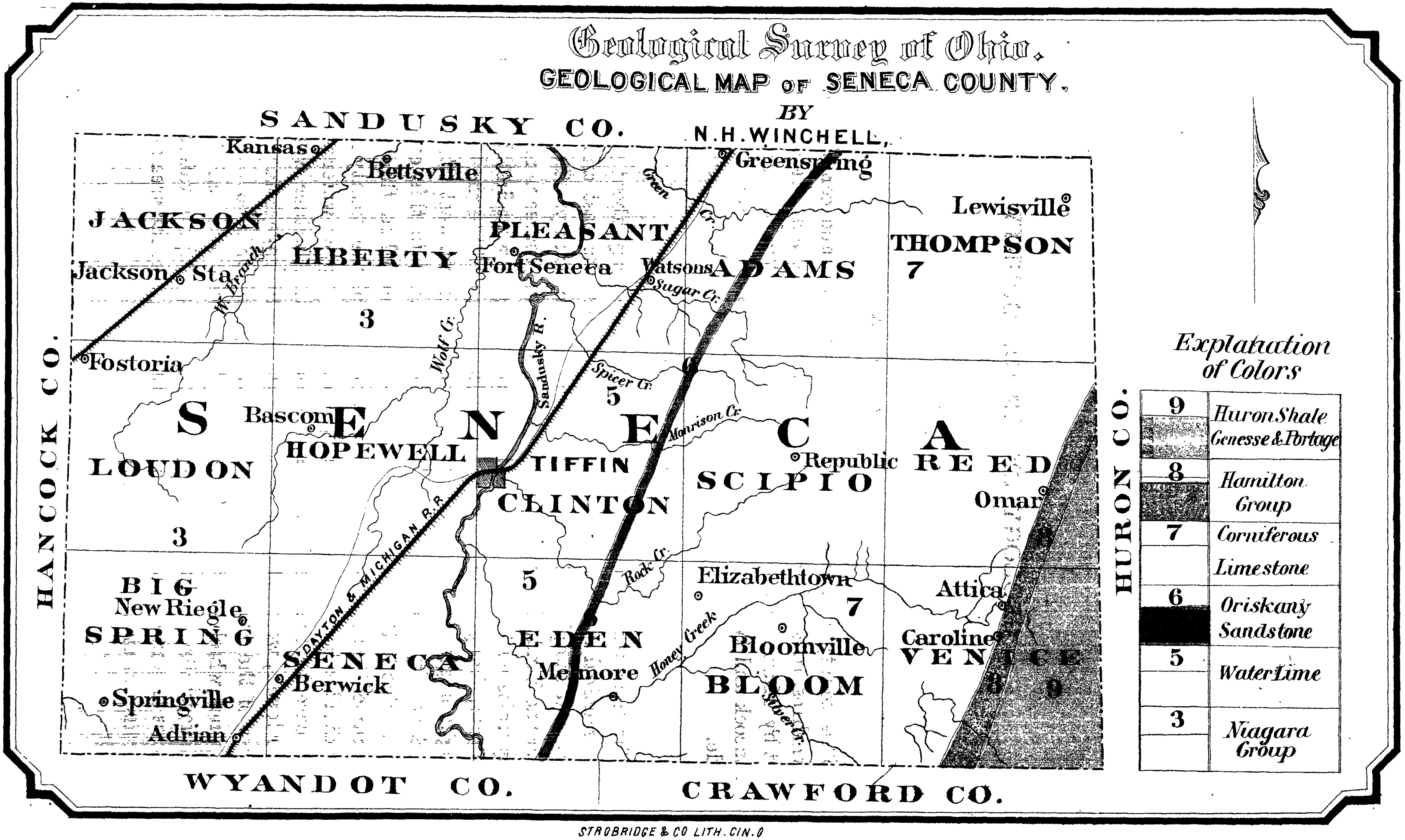
Wells for domestic use are generally obtained in the loose gravel within the drift, or in that sheet of gravel and sand which very often is the lowest part of the drift. As in Ottawa county, such wells are often artesian, and show the source of their water in the mineral impurities it contains. The water of the mineral spring at Greenspring, and of the spring in Sec. 7, Adams, Seneca county, issues from the rock, which, although exposed at no point within six miles, is probably the Niagara limestone. Wells, also, which do not reach the bottom of the drift, are sometimes supplied by slow seepage from the hard-pan, or by penetrating some of the sand or gravel beds contained within the drift. Wells from such higher beds of gravel are common outside the area of the Black Swamp. Within that tract, such beds of gravel are more rarely met with, above that lying on the rock. Some of the artesian wells in the northern part of the county are said to have a distinct saline taste, and must hence be derived from the Salina. The medicinal properties of the sulphureted water at Greenspring, are so marked as to induce the investment of considerable capital in the preparation of a water-cure establishment.

The following chemical analysis of this water by Prof. O. N. Stoddard, of Miami University, Oxford, Ohio, is published by the proprietors. No analysis has yet been made by the Survey:

Sulphate of lime in one gallon		105.41	grains.
Sulphate of magnesia	"	36.14	"
Sulphate of iron	"	6.53	"
Carbonate of iron	"	19.70	"
Carbonate of magnesia	"	22.39	"
Bromide of potassa	"	16.76	"
Chloride of potassa	"	2.48	"
Silica	"	6.10	"
Alumina	"	.98	"
Total		216.48	"
Carbonic acid gas in one gallon		96.48	cu. in.
Density		1.0258	
Temperature (summer and winter the same)		50°	Fah.

About four miles south-west from Fremont, Mr. John King sunk a drill a few years ago to the depth of six hundred and forty-five feet, with the primary object of petroleum, or at least an artesian overflow. Neither was obtained. No reliable minutes of the boring could be gathered.

Pieces of shale, said to have been brought up from a depth of about four hundred feet, styled "soapstone," have the appearance of the Cincinnati shale. There is, however, now, and has been since the drilling ceased, a discharge of inflammable gas, said to be derived from near the bottom of the well. Water which enters at about a hundred feet, and hence represses it with the force of a column of at least five hundred feet, greatly obstructs the escape of this gas. Were this pressure removed by tubing, the discharge of gas might be abundant enough to admit of use for illuminating purposes.


Geological Survey of Ohio.
GEOLOGICAL MAP OF SENECA COUNTY.
BY
N.H. WINCHELL,
SANDUSKY CO.
HANCOCK CO.
WYANDOT CO.
CRAWFORD CO.
HURON CO.
SENECA
JACKSON
LIBERTY
PLEASANT
ADAMS
THOMPSON
LOUDON
HOPEWELL
CLINTON
SCIPIO
REED
BIG SPRING
SENECA
EDEN
BLOOM
VENICE
TIFFIN
Kansas
Bettsville
Greenspring
Lewisville
Jackson Sta
Fort Seneca
Watsons
Fostoria
Bascom
Republic
Omar
Elizabethtown
Attica
Caroline
Bloomville
New Riegle
Berwick
Springville
Adrian
Melmore
Sandusky R.
Wolf Cr.
Green Cr.
Sugar Cr.
Spicer Cr.
Morrison Cr.
Rock Cr.
Honey Creek
Silver Cr.
DAYTON & MICHIGAN R.R.
Explatation of Colors
9 Huron Shale Genesse & Portage
8 Hamilton Group
7 Corniferous Limestone
6 Oriskany Sandstone
5 Water Lime
3 Niagara Group
STROBRIDGE & CO LITH. CIN. O

CHAPTER XXVII.

GEOLOGY OF SENECA COUNTY.

SITUATION AND AREA.

This county is immediately south of Sandusky, and contains fifteen townships, in the form of a rectangular parallelogram. It is bounded east by Huron county, south by Crawford and Wyandot, and west by Hancock and Wood. It is thirty miles long, east and west, and fifteen wide.

NATURAL DRAINAGE.

The Sandusky river, which intersects the county about midway, is the principal stream. Tributaries join it from the east and from the west, and complete the drainage system of the county. Those which enter the Sandusky from the west, have a general course north-east, till they unite with that stream; but those from the west first flow south-westerly, changing when within about five miles of the river, almost at a right angle, from that direction, and flow north-west till they join the Sandusky. This is a peculiarity not confined to this county, and may be due to the halting retreat of the glacier, when throwing down the unmodified drift with which that portion of the county is covered. The divides between these creeks, along their upper waters, would in that case, be the moraine accumulations, which, further west and at lower levels, were not sufficient to divert the drainage from the general course of the main valley. They may be compared to the extended moraines which shut off the St. Mary's and the Wabash rivers from their most direct course to Lake Erie, along their upper waters. These are less extended because the slope westward from the area of the Corniferous limestone is more abrupt.

SURFACE FEATURES.

This county presents more diversity of surface than Sandusky. The north-western part, including the townships of Jackson, Liberty and Pleasant, the northern half of Hopewell, and a small part of Loudon, presents the peculiar features of the lacustrine region, as already defined. The Niagara limestone rises in wide undulations above the surface of the drift, and is as frequently supplied with sandy accumulations and bowlders as in counties further north. The surface of these townships otherwise is very flat. The remainder of the county west of the Sandusky river, as well as the townships of Clinton and Eden on the east, are entirely without such limestone exposures, and the surface, when not broken by drainage valleys, is gently undulating. The eastern part of the county is considerably more elevated than the middle and western, and the surface is characterized at once by longer and more considerable undulations, which have the form very often of ridges, evenly covered by drift, running about north-east and south-west. This greater elevation is due to the greater resistance of the Corniferous limestone to the forces of the glacial epoch, not to upheaval, as many fancy; while the original inequalities in the drift surface have been increased by the erosion of streams. There are still, even in the eastern portion of the county, flat tracts where the drainage is so slow that the washings from the hillsides have leveled up the lower grounds with alluvium and marshy accumulations. In such cases, the elevated drift knolls are gravelly, and show occasional bowlders; but in the level tract which has been filled, no bowlders, or even stones of any kind, can be seen.

The streams are bounded by a flood-plain, and a single terrace. The latter, however, in the case of the smaller streams, is not well defined, especially where the general surface is not flat. The following heights of this terrace, above the summer stage of the river, were ascertained by Locke's level:

Sugar Creek, N. W. ¼ Sec. 27, Pleasant township	42 ft. 2 in.
Honey Creek, Sec. 20, Eden township	58 feet.
Sandusky river, Sec. 24, Seneca "	63 ft. 3 in.

SOIL AND TIMBER.

The soil, consisting principally of the old drift surface, is what may be termed a gravelly clay, with various local modifications. The principal exceptions are the alluvial flats bordering the streams, where the soil consists largely of a sandy marl, with varying proportions of vegetable matter; the depressions in the old drift surface, which have been slowly filled by peaty soil, and the sandy and stony ridges, in the towns

of Jackson, Liberty and Hopewell. With the exception of the marsh known as Big Spring Prairie, in the south-western part of Big Spring township, the whole county is in a tillable condition. Hence it is settled with a class of intelligent and prosperous farmers, who keep the land generally under constant cultivation.

The original forest, which is now to a great extent removed, embraced the usual varieties of oak, hickory, beech, maple, elm and ash.

GEOLOGICAL STRUCTURE.

The rocks that underlie the county have a general dip toward the east. Hence the Niagara limestone, in the western portion of the county, is succeeded by the higher formations in regular order in traveling east. They are the Water limestone, the Oriskany sandstone, the Lower Corniferous, the Upper Corniferous, the Hamilton shale, and the Huron shale (or the Black slate.) The eastern boundary of the Niagara enters the county a little east of Greenspring, in a south-westerly direction, and, crossing the Sandusky river at Tiffin, it turns westward nearly to the center of Hopewell township, where it turns again south-west, and leaves the county at Adrian. All west of this line is underlain by the Niagara, which is not divided into two belts, as in Sandusky and Ottawa counties. The strip of the Waterlime, which separates it in those counties, probably just indents the northern line of the county in Pleasant township. The outcropping edge of the Upper Corniferous is the only other geological boundary that can be definitely located. Those on either side are so obscured by the drift that their located positions on the map must be regarded as conjectural. In general, however, the Waterlime underlies a strip along the eastern side of the Niagara area, about five miles in width on the north, but widening to nine miles on the south. The Lower Corniferous underlies the western part of Bloom and Scipio townships, and the eastern part of Adams. The Upper Corniferous occupies the most of Thompson and Reed townships, the western portion of Venice, and the eastern portion of Bloom and Scipio. The Hamilton and the Black shale have not been seen in outcrop in the county, but are believed to underlie a small area in the south-eastern portion of the county. The Black shale may be seen in the valley of Slate Run, Norwich township, Huron county.

The *Niagara* shows the following exposures:

IN JACKSON TOWNSHIP.

S.W. ¼ Sec. 36. In a little creek. No dip discoverable.

Sec. 22. A prominent ridge is crossed and slightly excavated by the railroad. The ascent is so gentle the grade rises over it.

N.W. ¼ Sec. 31. Of the Guelph aspect, showing numerous fossils; used for making roads, and for lime.

IN LIBERTY TOWNSHIP.

S.W. ¼ Sec. 4. In the W. Branch of Wolf creek; dip six or eight degrees west.

S.E ¼ Sec. 5.

Sec. 3. Half a mile west of Bettsville. Frequent exposure along the W. Branch of Wolf creek. When observable, the dip is to the west.

Sec. 10. Along the east line of the section, in the form of ridges.

N.E. ¼ Sec. 28.

N.W. ¼ Sec. 2. Horizontal; in the W. Branch of Wolf creek, setting back the water nearly a mile.

N.W. ¼ Sec. 24. Considerably quarried for foundations and abutments of bridges.

S.W. ¼ Sec. 30. By the roadside.

N.E. ¼ Sec. 36. In Wolf creek.

S.W. ¼ Sec. 34.

S.W. ¼ Sec. 31. In thick beds—used by Mr. George King in the construction of his house; dip 5° N.E.

N.W. ¼ Sec. 29.

IN PLEASANT TOWNSHIP.

N.W. ¼ Sec. 19. In the bed of Wolf creek. Dip N.E. Glacial scratches S. 56° W.

N.W. ¼ Sec. 20. In the bed of the river at Fort Seneca, just below the dam, a fine-grained, bluish limestone; has been a little quarried for use on roads. But owing to its hardness and the unfavorable location, it was not regarded suitable. It probably belongs to the Niagara, although the opportunities for examination were too meager to determine certainly.

Center and S.E. ¼ Sec. 28. In thick beds, in Spicer creek.

IN HOPEWELL TOWNSHIP.

N.E. ¼ Sec. 22. Has the aspect of the Guelph, on the land of Henry W. Creeger. Surface exposure.

Sec. 16. Where the road crosses Wolf creek.

In these surface exposures very little opportunity is afforded for ascertaining the lithological characters, or the mineralogical and fossil contents of the formation. The chief exposure of the Niagara within the county is in the Sandusky river, between Tiffin and Fort Seneca.

From Tiffin, descending the Sandusky river, rock shows constantly, to within half a mile of the line between Clinton and Pleasant townships. Throughout the most of this distance the dip of the formation (Niagara) is from five to ten degrees toward the south-west, but with various flexures and undulations in all directions. The thickness of bedding exposed is between fifty and sixty feet. The following minutes on this exposure will show the undulations in the dip of the beds, and

the manner of occurrence of the fossiliferous beds which have by some been regarded as a distinct member of the Upper Silurian, above the Niagara. They make, here, a sudden appearance within the formation, having horizontal continuity with the more usual, hard, gray and thick-bedded Niagara, which contains fewer fossil remains:

Ascending the river along the left bank from the little island on Sec. 29, in Pleasant township, the Niagara is first met within a quarter of a mile, with a dip N.E. 10°, showing glacial furrows S. 44° W.—exposed		3 ft.
A quarter of a mile further south, at a dam for a sawmill, with dip still N.E.—lower exposed		4 ft.
About one-fourth mile above the dam, dip still N.E.		6 ft. 6 in.
The rock then begins to dip S.W., and returns—about	—3 ft.	
Dip continuing S.W., returns	—3 ft.	
Dip N.E		2 ft.
Rock visible, no dip discernible for sixty rods.		
Gentle dip S.W. for thirty rods	—2 ft.	
Gentle undulations:—		
N.E		3 ft.
S.W	—3 ft.	
N.E		2 ft. 6 in.
S.W.	—3 ft.	
N.E		3 ft.
Beds dip N.E. nearly a mile, about with the descent of the stream, nearly to the next dam. Exposed, perhaps		4 ft.
Then begins a rapid dip S.W.—seen	—18 ft. 10 in.	
Covered by the dam, not seen, at least	—10 ft.	
Then rises with gentle dip N.W		5 ft.
The beds then appear horizontal about half a mile. This extends to a point two miles from Tiffin, where the rock passes out of sight. It next appears a few rods further up, opposite a brick flouring-mill, in a perpendicular exposure of fourteen feet. Add one-half as dip S.W.	—7 ft.	
The river then makes its way over fifteen feet of beds, extending nearly to the first dam north of Tiffin; gentle dip S.W	—15 ft.	
S.W. still (to the bottom of the *Guelph?*)	—8 ft.	

Here that phase appears which has been named the *Guelph*. For a few rods the dip is rapid to the N.E., having much the appearance of unconformability in the bedding. There is a sudden upward flexure of the overlying beds, for this phase here is *under* as much as ten feet of hard gray crystalline Niagara, like that already passed over, containing almost no fossils. This, however, in passing further south, becomes soft, light buff and fossiliferous: below, much broken and confused, or spongy and massive; yet lying horizontally and containing the peculiar fossils of the Guelph. Several small openings in these

beds for lime-burning reveal *Megalæmus Canadensis*, Hall. *Pleurotomaria* and *Pentamerus*, with species of *Murchisonia* and *Favosites*. The dip then returns S.W. as rapidly as it rose. Add for these fossiliferous beds.. —15 ft.

Here comes in the Waterlime, showing the fossils *Leperditia alta* and *Atrypa Sulcata?* It is separated from the Niagara, which, just within the limits of the city, has become gray, crystalline and thick-bedded again, without visible fossils, by a bed of two or three inches, which, uniting the lithological characters of the two formations, serves to determine not only the place but the reduced limits of the Salina. Ten rods further south the bluish gray and hard Niagara again bulges upward in a gentle swell, disclosing, below, the light buff and porous layers, while the Waterlime disappears. Continuing so about ten rods, the beds return to the same level, nearly horizontal, but the Waterlime is not shown again till within the city limits, where it has been quarried between the highway and the railroad bridges, and dips S.W.

Total S.W. dip	—87 ft. 10 in.	
Total N.E. dip..		33 ft.
Actual S.W. dip of the formation..		54 ft. 10 in.

From this it appears that the Niagara limestone, especially the uppermost fifty-five feet, is, in general, a gray, crystalline, rather fine-grained, compact or slightly visicular and unfossiliferous mass; and that the fossiliferous parts are rough and visicular, of a light buff color, apt to crumble under the weather, and not horizontally continuous.

The green shale, which, in Sandusky county, represents the *Salina*, has nowhere been seen in Seneca county. The only place within the county where the "junction" of the Niagara and Waterlime has been observed, is in the quarries at Tiffin. Within the corporate limits, a few rods above the swing bridge for the highway crossing, a quarry has been opened in the left bank of the Sandusky, which may be designated *Quarry No.* 1. The Niagara here shows in a broad surface exposure, over which the river spreads, except in its lowest stage. The quarry has not penetrated it, but the overlying Waterlime beds have been stripped off, showing a section of twelve feet in their beds belonging to *phase No.* 3. This lies conformably on the Niagara, so far as can be seen, the separating surface presenting no unusual flexures or irregularities. The only trace of the Salina is in the tendency of the color and texture of the Niagara toward those of the Waterlime, visible through its last three or four inches. It is bluish-drab, porous, crystalline, with some indistinct, greenish lines and spots. It contains much calcite and some galena. From this character it passes immediately into a bluish-gray,

crystalline rock, in thick, firm beds, with spots of purple, heavy and slightly porous, the cavities being nearly all filled with calcite.

The principal exposures of the *Waterlime* are in the quarries at Tiffin.

Section of Quarry No. 1, *in descending order.*

No. 1.	Waterlime in thin, drab beds, like the Fremont quarries of June and Quilter. Exposed	12 ft.	
No. 2.	Porous, bluish-drab, with greenish streaks, containing much calcite and some galena		3 in.
No. 3.	Firm, gray Niagara, in thick beds. Exposed	1 ft.	

Quarry No. 2 is located a quarter of a mile above the last, on the opposite or right bank of the river, and is known as the *City Quarry.* The dip is here S. W. six or eight degrees. Supposing the dip is uniform between Quarries Nos. 1 and 2, there must be an unseen interval of twenty-five or thirty feet of the formation separating them.

Descending Section of the Waterlime at Quarry No. 2, *Tiffin.*

No. 1.	Very compact; fine-grained; in beds of six to thirty inches. The fracture is a brownish-drab, and weathers light drab; sometimes porous or brecciated	8 ft.	4 in.
No. 2.	Thin-bedded; more earthy; rough in patches, and feeling like a fine-grained sandstone. The general facies is like Nos. 3 and 7..		10 in.
No. 3.	Very compact, fine-grained beds of one or two inches; broken; irregular; separated with bituminous films which weather first blue, then chocolate. The fracture is a brownish-drab, and weathers light drab. It is sometimes porous or slightly brecciated. When fine-grained and compact it shows acicular cavities	2 ft.	2 in.
No. 4.	Same as the last, except the beds are even	1 ft.	
No. 5.	Very compact; fine-grained; gray; crystalline; with occasional amorphous cavities. In one bed	1 ft.	2 in.
No. 6.	Very compact and fine-grained; in even beds of one to two inches. The separating bituminous films weather blue, turning to chocolate; the brownish-drab, fractured surface weathers light drab; in some places with fine acicular cavities	2 ft.	3 in.
No. 7.	Very compact and fine-grained; in beds of one to two inches; in broken, irregular and lenticular; separated by bituminous films, which weather blue and then chocolate; fracture brownish-drab; weathering light drab; in some places with fine acicular cavities. This being the lowest exposed, it has been stripped of the overlying beds for the space of several rods. The exposed upper surface of the bedding is very uneven, being thrown into curious mound-like elevations of two to six or eight inches, and a foot to three feet across, which do not show any system of arrangement. Considerable bituminous		

matter is disseminated through them, not included in the texture of the rock, which is very hard and crystalline, but in thin films between the beds, or in irregular deposits within the little mounds, or about their peripheries. The laminations which form these mounds are thinner than the regular bedding, and are sometimes not more than half an inch thick. They never show concave surfaces upward (hence the mounds are not concretions,) but variously modify and fit to each other like a quantity of semi-fused and inverted plates or watch-glasses, the bituminous matter acting as a cement. Exposed... 2 ft.

Total exposed.. 17 ft. 9 in.

The characteristic fossil, *Leperditia alta*, may be seen in nearly all parts of this section, but it was especially noted in Nos. 3 and 7. This rock is all hard and crystalline, but with a fine grain. No. 3, without careful examination, might be mistaken for Niagara, if seen alone. When broken into fragments for roads, the color of the pile, weathered a few months, is a pleasant, bluish-gray. Yet on close examination the blue tint vanishes, and the stone shows a drab, a dark or brownish drab, a black, and a bluish-gray, (the last two only on the lines of the bedding,) depending on the fracture or surface examined.

The river just in the southern limits of the city is flowing east. The rock can be followed along the same bank of the river eighteen or twenty rods from the foregoing quarry, and has an irregular surface exposure throughout that distance, with a continuous dip south-west. The rock then follows the bluff, which strikes across a patch of river bottom, and is not seen again until a mile further up the river. It is here quarried and burned into lime. The dip is in the opposite direction, that is, toward the north. This is quarry No. 3.

Descending Section of the Waterlime, Quarry No. 3, Tiffin, Seneca County, O.

No. 1.	Soft; drab; slightly porous	1 foot.
No. 2.	Hard and close-grained; gray and drab	1 ft. 2 in.
No. 3.	Brecciated, (like Put-in-Bay Island,) with hard and soft; drab and dark drab; sometimes cavernous, with considerable calcite, and porous	4 feet.
No. 4.	In one bed. } Hard; gray; porous, with celestine	2 feet.
No. 5.	In one bed. } Very porous; soft; drab	1 foot.
No. 6.	Hard; porous; dark drab	1 foot.
No. 7.	Soft; drab; veined tortuously with darker drab; in one bed	2 ft. 4 in.
No. 8.	Porous; gray and drab (mixed); with coarse but firm texture	1 ft, 3 in.
No. 9.	Hard, drab beds, but porous	2 feet.
No. 10.	Coarse, drab beds; porous; rather soft under the hammer	12 feet.
	Total	27 ft. 9 in.

This rock is quite different in most of its external aspects from that described in the last two sections, and it probably overlies them. It is much more loose-grained and porous, and is almost without bituminous films. The beds are generally six to twelve inches, but sometimes three feet in thickness. It has more constantly the typical drab color of the Waterlime, and it shows, besides the *Leperditia alta*, another bivalve like *Atrypa sulcata*, and a handsome species of *Orthis*, also a coarse Favositoid coral, all of which are often seen in the Waterlime.

In the S.E. ¼ Sec. 22, Hopewell township, Mr. Henry W. Creeger quarries the Waterlime in the bed of Wolf creek; dip south six or eight degrees.

The Waterlime appears in thin, drab beds, at the bridge over the Sandusky, N.E. ¼ Sec. 23, Seneca township, with undulating dip.

S.E. ¼ Sec. 29, Clinton township, where the road crosses Rock creek, the Waterlime is exposed, having the features of No. 8, of Quarry No. 3, at Tiffin.

The *Oriskany Sandstone* is nowhere exposed in this county, but its line of outcrop probably passes through Adams, Clinton and Eden townships.

The *Lower Corniferous* has been observed in the following places:

S.W. ¼ Sec. 1, Eden township. Along the bed of a little creek tributary to Rock creek, a magnesian, buff, granular limestone is exposed. It has no fossils, so far as can be seen in the meager outcrops. It is also seen in the banks along the creek, on the farm of Mr. Ferguson. It was formerly quarried to a limited extent, and used for rough walls. It is rather soft at first, but is said to become harder when the water is dried out. No dip is discoverable.

N.W. ¼ Sec. 17, Bloom township. In the bed of Honey creek, near Mr. Philip Heilman's residence, the same rock may be seen; dip uncertain, but it appears east and south-east.

N.W. ¼ Sec. 20, Bloom township. In the right bank of Silver creek there is an exposure of higher beds of the Lower Corniferous, as follows, from above:

No. 1.	In beds of two to six inches; buff and dark buff; magnesian; very slightly fossiliferous; some hard and crystalline, some soft and spongy. These edges do not appear slaty. They have been long weathered, and lie loose. This is near the junction of the Lower and the Upper Corniferous	10 ft.
No. 2.	Magnesian; rather hard; crystalline; non-fossiliferous; buff when dry; fine-grained; banded with darker buff, or with brown when in thicker beds. Beds ¼ in. to 2 in. Their edges appear slaty	2 ft.
	Total	12 ft.

Lying nearly horizontal five or six rods, at the east end of the bluff, the beds dip east and disappear. A little west of this exposure the magnesian, non-fossiliferous, thick-bedded characters of the Lower Corniferous may be seen in the bed of the creek. Eighteen or twenty rods to the east, the features and fossils of the Upper Corniferous appear in an old quarry by the road-side, where the dip is E.N.E.

S.W. ¼ Sec. 3, Scipio township. Along the channel of Sugar creek, on land of Enoch Frey, a stone is exposed which appears like Lower Corniferous. It is soft and coarse-grained, without visible fossils. A pond which has precipitous banks, and is said to sometimes become dry, located near this place, is probably caused by subterranean disturbance and erosion.

The quarry of Mr. David Wyatt, N.W. ¼ Sec. 1, Scipio township, is in a thin-bedded, buff stone, which has no tendency to blue, without fossils, and included within the Lower Corniferous.

The Lower Corniferous is also exposed S.E. ¼ Sec. 34, Adams township, along the public road.

N.E. ¼ Sec. 26, Eden township. A fine-grained argillaceous, gray rock, weathering buff, without visible fossils, appears in the road. It seems apt to break into angular pieces three or four inches across. It is rather hard. It is probably included within the Lower Corniferous.

The opportunities for observing the lower portion of the Corniferous within the county are not sufficient to warrant a general section and description.

The *Upper Corniferous*, owing to its greater hardness and toughness, was not so generally destroyed by the ice and water of the glacial epoch, and now may be more frequently seen, thinly covered with coarse drift, occupying the highest parts of the county, and forming the main watershed. The coarseness of the drift on these higher tracts is owing to the washings by rains and freshets since the close of the glacial epoch. It is an unassorted hardpan, and sometimes covers glacial *striæ* in the rock below.

This part of the Corniferous is exposed in the following places within the county. It furnishes a very useful building stone, and is extensively used for all walls, foundations, and some buildings:

IN THOMPSON TOWNSHIP.

N.W. ¼ Sec. 20. It closely underlies the most of the section. The drift being thin, the soil sometimes shows fragments. A quarry is owned by Mr. John Paine.

S. W. ¼ Sec. 16. Mr. George Good's quarry; beds horizontal; in the midst of a field in fine cultivation, with a surface gently undulating; drift at the quarry eight inches, but rapidly thickening further away.

S. W. ¼ Sec. 16. Samuel Rogers's quarry exposes about eight feet perpendicular; beds about horizontal.

S. W. ¼ Sec. 14. Reuben Hartman's quarry exposes about eight feet of blue thin beds, which seem to have been shattered, falling toward the west, the firm beds having a slight dip toward the north-east. Large, handsome flagging is obtained at this quarry.

N. E. ¼ Sec. 2. Benjamin Bunn's quarry. There are here about three feet of drift over the rock. The beds are exposed about six feet perpendicular. Dip not observed, although there is a falling away by fracture toward the west.

S. W. ¼ Sec. 1. Charles Smith's quarry faces west. Indeed the same is true of Hartman's and of Bunn's. Mr. Rogers's is an irregular opening, facing mostly north and west. Mr. Good's faces north and east.

S. E. ¼ Sec. 1. In the edge of Huron county, Mr. George Sheffield has a quarry in horizontal beds; gravelly soil eighteen inches.

S. E. ¼ Sec. 1. Quarry of William Clemens.

N. E. ¼ Sec. 21. Quarry of Joseph Shirk. This consists of a mass of shattered and dislodged beds, from which, however, good stone is taken. In one place, a mass showing a perpendicular thickness of five feet, is twisted away from its original position, the planes of jointing indicating where it ought to lie. It is removed two feet from its natural place. The projection beyond the face of the other beds tapers, in the distance of about fifteen feet, to a few inches, and is hid by debris.

N. E. ¼ Sec. 15. Quarry of John M. Krauss.

N. E. ¼ Sec. 29. Quarry of Mrs. Joseph Hoover.

N. E. ¼ Sec. 10. Quarry of Isaac Carn.

N. W. ¼ Sec. 11. Quarry of Tunis Wygart.

N. W. ¼ Sec. 2. Quarry of heirs of Grimes.

Many others also have small openings in the rock in this township. They are nearly all in the midst of cultivated fields, and there is a remarkable absence of bowlders, although the rock is seen sometimes projecting above the surface. There are a few bowlders, but they are such as belong in the drift, and have been dug out by the erosion of streams, or by man. They are not thick about rocky outcrops, as in the lacustrine region.

IN BLOOM TOWNSHIP.

N. W. ¼ Sec. 11. Lewis Fisher has an extensive quarry in the Upper Corniferous, in the valley of a little tributary to Honey creek. About fifteen feet of bedding are exposed, lying nearly horizontal. The lowest beds are about eighteen inches in thickness, and softer, yet of a blue color like the rest. In working Mr. Fisher's quarry it has become necessary to remove about ten feet of hardpan drift.

N. E. ¼ Sec. 10. Jacob Detweiller's quarry is also an extensive opening, and exposes beds a few feet lower than Mr. Fisher's. The lowest seems to be lighter colored, and must be near the bottom of the Upper Corniferous. A stream disappears in this quarry in time of freshet.

S. W. ¼ Sec. 3. Henry Determan's quarry is located in the valley of Honey creek.

N. E. ¼ Sec. 20. Along the banks of Silver creek there is considerable exposure o

the Upper Corniferous, and it is extensively wrought by Abram Kagay. The beds here have a continuous dip E. S. E., affording opportunity for the following section:

Descending Section of the Upper Corniferous, at Abram Kagay's, Sec. 20, Bloom township, Seneca county.

No. 1.	Fossiliferous beds with chert which weathers white; thin-bedded; of a bluish-gray color	7 feet.
No. 2.	Thin, flaggy, lenticular beds; fossiliferous; drab-buff color; hard, brittle, and sometimes with vermicular impressions	4 feet.
	[NOTE.—No. 2 would probably be thicker bedded and bluish if freshly exposed.]	
No. 3.	The same as No. 2, but in more even beds	28 feet.
	Upper Corniferous exposed	39 feet.

N. W. ¼ Sec. 29. Noah Einsel has a handsome quarry, in beds which dip E. N. E.

N. W. ¼ Sec. 20. Reed township. The Upper Corniferous is quarried by Mr. Armstrong.

THE DRIFT.

Throughout this county, this deposit lies as it was left by the glacier. The mass of it is an unassorted hardpan, but it shows locally the glacial stratification incident to streams of water arising from the dissolution of the ice. Such cases of stratification are most common in the great valleys, where the waters necessarily accumulated. They are by no means common, nor uniform in their location in the drift vertically. In some cases, the stratification rises nearly or quite to the surface, or prevails to the depth of thirty or forty feet. In others, it embraces one or more beds of hardpan, which have irregular outlines. In Sec. 20, Eden township, the banks of Honey creek were particularly noted, and may be described as follows:

No. 1.	This is imperfectly exposed, but wherever seen is unassorted hardpan, with considerable gravel. It forms the soil of the county, and is of a brownish yellow color	25 feet.
No. 2.	Is blue, and composed of alternating beds of compacted hardpan, containing waterworn and scratched pebbles of all kinds and sizes, apparently unassorted and unstratified, and beds of coarse sand, extremely fine sand, and coarse gravel. From the sand and gravel layers issue springs of ferriferous water. The sand layers graduate sometimes into impervious clay-like beds, and can hardly be called sand. The lowest seen in No. 2 is a layer of eighteen inches, at least, of clean sand	30 feet.
No. 3.	Talus of rounded pebbles and stones, mostly limestone, and frequently stained with iron oxyd	3 feet.

The thickness of the drift cannot be stated with certainty. At Attica,

in the township of Venice, wells penetrate it to the depth of sixty feet without striking the rock. This is the highest point within the county, and the general surface is rolling.

MATERIAL RESOURCES.

BUILDING STONE.

Next to the products of the soil, the most important resources of Seneca county consist in the products of the quarries. Throughout most of the county there is no difficulty in obtaining good building stone, although the best quarries are situated a little unfavorably for the townships of Loudon, Big Spring, Seneca, Eden, Pleasant, Venice and Reed. The quarries at Tiffin furnish stone throughout a radius of many miles in all directions, while those in Bloom township supply a great tract of country south and east. The quarries in Thompson township, although located in the Upper Corniferous, and affording one of the best qualities of stone in north-western Ohio, and favorably exposed for working, are less developed than similar openings in Bloom township. This is doubtless due to the superior advantages of quarries further north, and at Bellevue, in Sandusky county, for reaching market and for shipment by railroad.

LIME.

For *lime* the Niagara and Waterlime formations are chiefly used. They are more easily quarried and more cheaply burned than the Upper Corniferous. Both are burned at Tiffin, but the kilns are rude, and the expense of burning is greater than where the improved kiln is employed.

CLAY.

Clay for brick and red pottery is found of suitable quality in all parts of the county. Many establishments for the manufacture of brick employ the surface of the ordinary hardpan, including even the soil. Others reject the immediate surface, which contains roots and turf, and burn the hardpan from the depth of a foot or two. This material, although liable to contain pebbles of limestone, which injure the manufactured article, generally has it in so small quantity, and in so comminuted a state, as to require no other flux for the silica; and the tile, brick and pottery made in this way are suitable for all purposes where no great degree of heat is required. Mr. J. H. Zahm, of Tiffin, after many careful experiments, has succeeded in making a good quality of hydraulic cement, by mixing the finest of the drift clay, in proper parts, with ordinary carbonate of

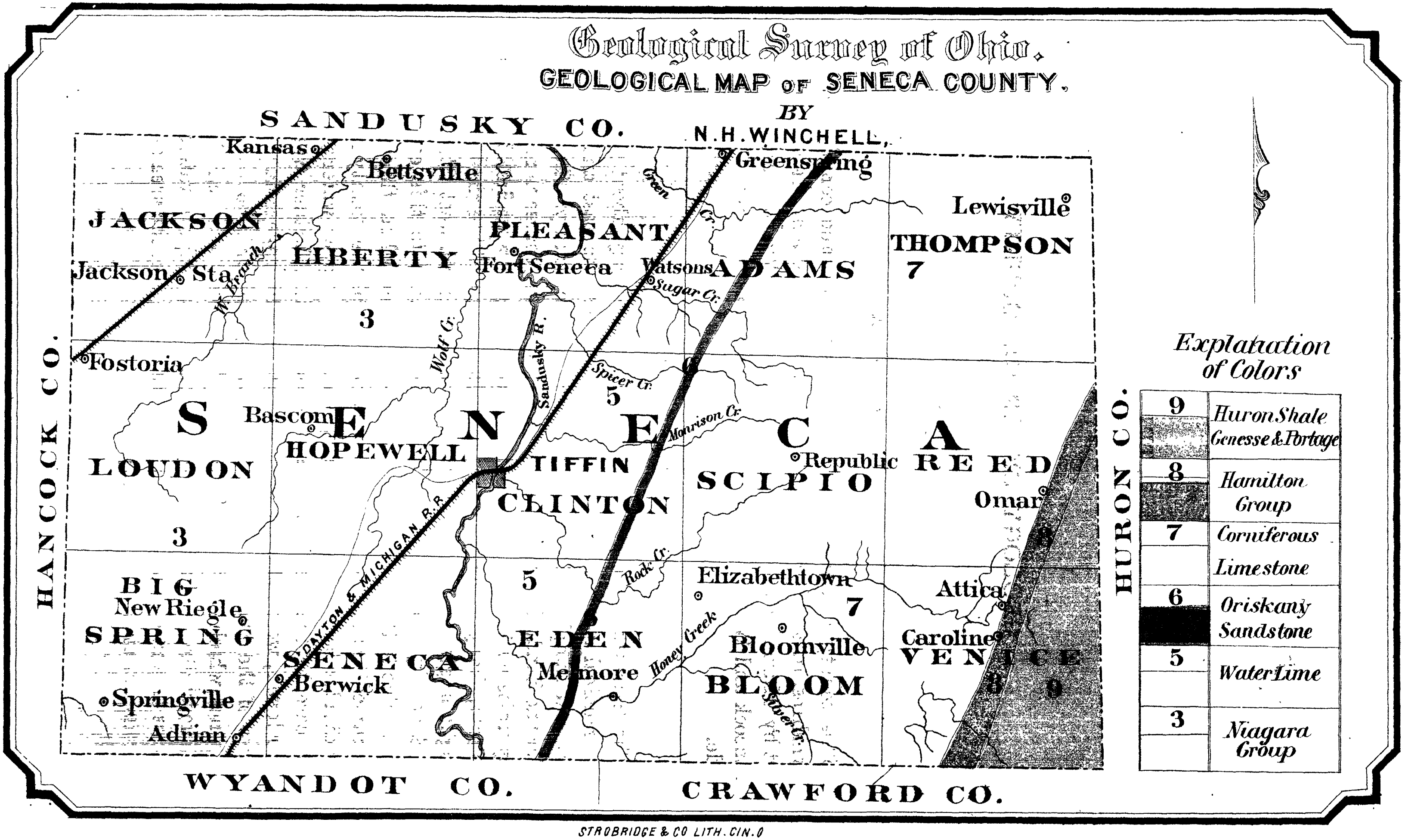
lime or tufa. He has also produced from the drift clay near Tiffin, by making proper selections, a very fine pottery, some of which cannot be distinguished from the *terra cotta* ware used for ornaments and statues. It has a very close, vitreous fracture, a smooth surface, and a dark-red or amber color. From the drift clay near Tiffin, Mr. Henry W. Creeger also obtains a fine material for pottery, and for glazing with salt.

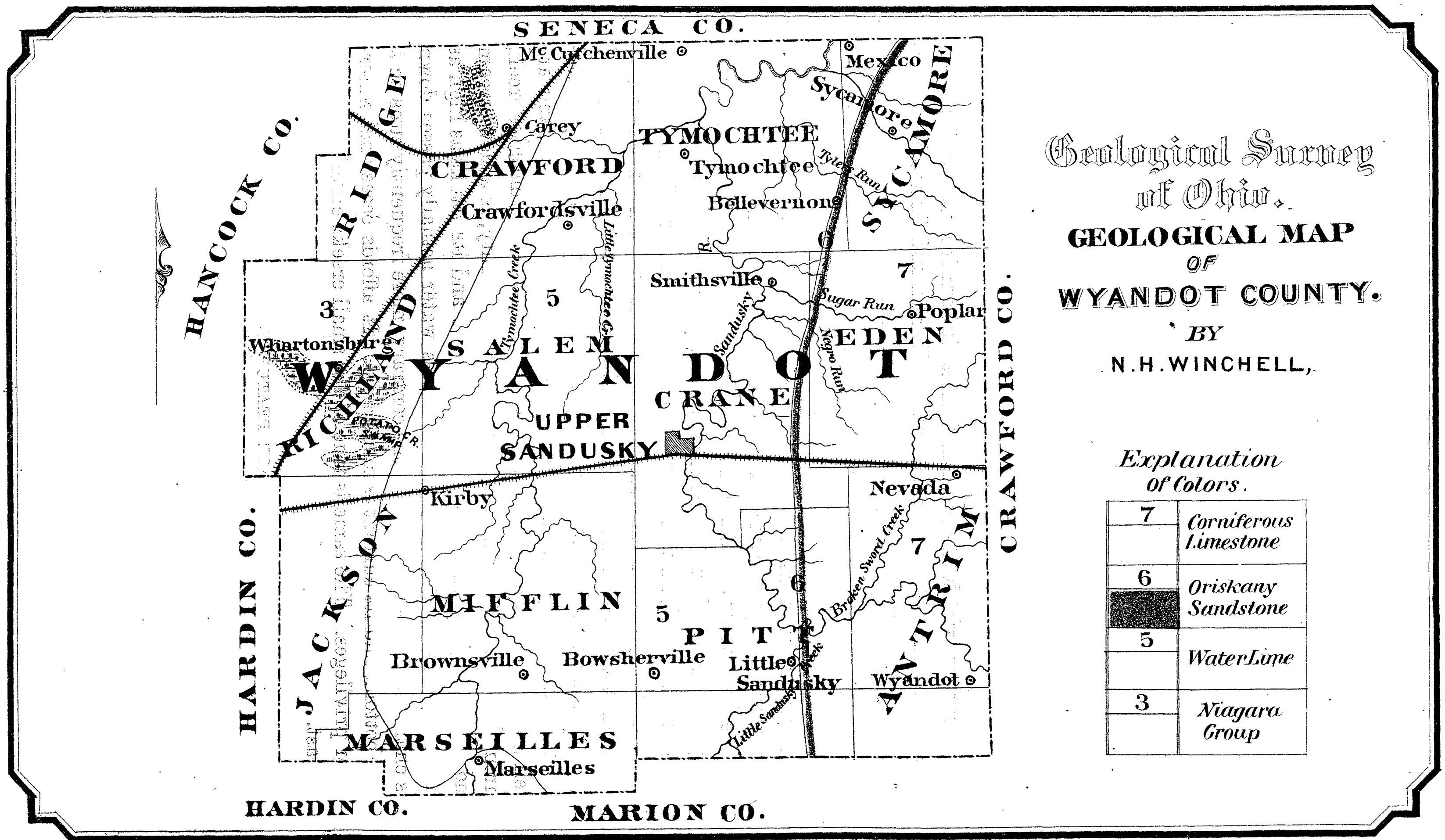
BOG-IRON ORE.

Before the development of the Lake Superior and Missouri iron mines, one of the principal sources of iron in the north-west was the bog ore deposits which are scattered over much of the country. In north-western Ohio the numerous furnaces which were employed on these deposits along the south shore of Lake Erie, and in counties further south and west, rendered bog ore an important item of mineral wealth. It produces an iron known as *cold short*, owing to the presence of phosphorus, which cannot be used for wire or for sheet iron, but is valuable for castings. On the contrary, iron from the ores which contain sulphur as an impurity, or silicon, is friable or brittle while hot, and is distinguished as *red short*. When these two qualities occur in close proximity, or in circumstances favorable for transportation, they may be mixed in the process of smelting, and the resulting iron is greatly improved. The Lake Superior ores, which are the only ones smelted in the furnaces of north-western Ohio, are nearly or quite free from sulphur, and hence at the present time the bog ores possess but little commercial value. It will be only in connection with the sulphur ores of the Coal Measures, in the south-eastern part of the State, that the bog ores can be made of any mineral value.

In Seneca county bog ore occurs in a number of places. It is usually not in quantities sufficient to invite expenditure of capital, and, in the absence of abundant fuel, it will probably never be of any economical value. It was met with on the farm of William B. Stanley, about two miles south-east of Tiffin, where it underlies a peat bog covering irregularly perhaps fifteen or twenty acres.

It also occurs on the land of Mr. Foght, S.E. ¼ Sec. 27, Seneca township. It has been taken out here in large blocks, roughly cut while wet, and set up for back walls in rude fire-places. On being exposed to the air, or especially to fire, it becomes cemented and very hard. There is also a deposit in Sec. 11, Clinton township, exactly on the south line of the Seneca Indian Reservation.


Geological Survey of Ohio.
GEOLOGICAL MAP OF SENECA COUNTY.
BY
N. H. WINCHELL.
SANDUSKY CO.
HANCOCK CO.
HURON CO.
WYANDOT CO.
CRAWFORD CO.
SENECA
JACKSON
LIBERTY
PLEASANT
ADAMS
THOMPSON
LOUDON
HOPEWELL
CLINTON
SCIPIO
REED
BIG SPRING
SENECA
EDEN
BLOOM
VENICE
Kansas
Bettsville
Greenspring
Lewisville
Jackson Sta.
Fort Seneca
Watsons
Fostoria
Bascom
Tiffin
Republic
Omar
Elizabethtown
Attica
Caroline
New Riegle
Bloomville
Melmore
Berwick
Springville
Adrian
W. Branch
Wolf Cr.
Sandusky R.
Green Cr.
Sugar Cr.
Spicer Cr.
Morrison Cr.
Rock Cr.
Honey Creek
Silver Cr.
Dayton & Michigan R.R.
Explanation of Colors
9 Huron Shale Genesse & Portage
8 Hamilton Group
7 Corniferous Limestone
6 Oriskany Sandstone
5 Water Lime
3 Niagara Group
Strobridge & Co Lith. Cin. O



STROBRIDGE & CO. LITH. CIN. O.

CHAPTER XXVIII.

GEOLOGY OF WYANDOT COUNTY.

SITUATION AND AREA.

This county, which lies south of Seneca, is bounded east by Crawford, south by Marion and Hardin, and west by Hardin and Hancock, containing eight square miles more than eleven townships.

NATURAL DRAINAGE.

Being near the great water-shed of the state, just on its northern slope, it contains no large streams. The Tymochtee creek, with its tributaries, and the headwaters of the Sandusky river, comprising the Little Sandusky and the Broken Sword creeks, and the small stream known as Sycamore creek, Tyler's run, Sugar run, Negro run and Rock run, are the drainage system of the county. Their general course is due north, except that the eastern tributaries of the Sandusky, and perhaps for the same reason as in Seneca county, have a direction westerly or southwesterly, until they descend upon the area of the Waterlime, and are well within the drainage valley of the Sandusky. The Tymochtee creek, throughout the most of its course in Wyandot county, is a slow stream and has a clay bottom. Its valley is as wide and its banks as high as those of the Sandusky itself, although less water actually passes down its channel. The Sandusky, on the contrary, more frequently runs on a rock bottom, and its current is more rapid. It affords occasional water-power privileges. The same is true of the small creeks entering it from the east.

SURFACE FEATURES.

The topography of this county is quite simple. The western half is gently undulating or flat. The excavated valley of the Tymochtee creek, which is usually about a hundred rods wide, and rarely exceeds two

hundred rods, presents, in its abrupt descents, the most noticeable changes of level. There are several extensive prairie-like tracts, which have a black soil and were never clothed with forest. They are in the higher levels, and give rise to some of the tributaries of Tymochtee creek. One is north and west of Carey, extending largely into Seneca and Hancock counties, known as Big Spring Prairie. Another covers much of the township of Richland, known as Potatoe Swamp, and a third occupies the south-eastern part of Mifflin, and the south-western part of Pitt townships, extending also into Marion county. The Cranberry Marsh, in Jackson township, also extends largely into Hancock county. That tract known as Cranberry Marsh, in Crane township, and the marshy tract in the center of Tymochtee township, are of less extent, but in every way analogous to the rest. These marshes were, probably, once the sites of lakes, which have become filled by the slow accumulation of vegetable matter, and the washing in, from the adjoining land, of the finer materials of the drift. This is particularly noticeable about the ridges and knolls which enclose Big Spring Prairie. Besides these untillable marshes, most of the territory lying between the Tymochtee creek and the Sandusky river has a black, loamy soil, and was once, probably, subject to inundation by those streams, although now it is generally laid out in fine farms.

East of the Sandusky river the surface is more broken, and there is a noticeable ascent from the area of the Waterlime to that of the Corniferous. There is a tract of elevated land, like a fragment of a glacial moraine, along the west side of Broken Sword creek, extending from Eden township to Little Sandusky, in Pitt township. Besides these undulations in the original surface of the drift, that part of the county east of the Sandusky is subject to erosions by frequent small streams, which have worn channels in the drift, and sometimes in the rock itself.

Where the streams of the county run through level tracts, they present the usual terrace and flood-plain. The former is the old drift surface, and rises from twenty to forty feet above the level of the water. The latter, which is constantly changing its position and its contents, is, of course, dependent on the greatest freshet rise of the stream. Along the Tymochtee creek it is sometimes twelve feet or more above the summer stage of the stream.

CHARACTER OF THE SOIL.

The prevailing feature of the soil is clay. This, however, is variously modified. In the higher parts of the county it is gravelly, and often contains stones or bowlders. It is compact, and almost entirely without

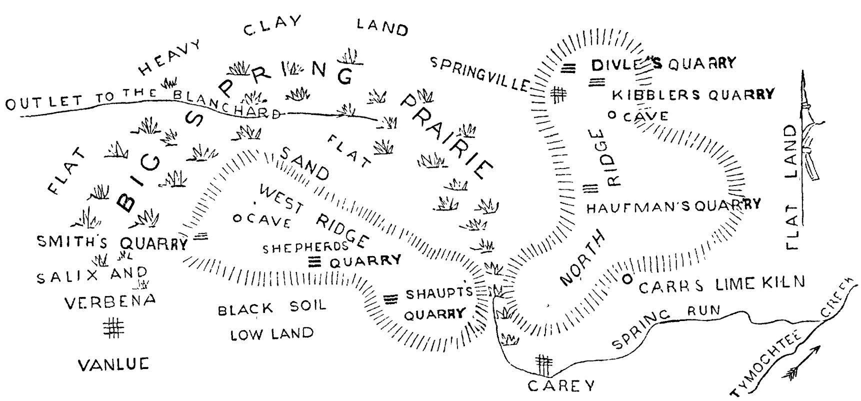
stones or even gravel in the level tracts, especially where there has been a gradual filling up, with slow or imperfect drainage. The soil of the prairies, which is black, consists very largely of vegetable matter in various stages of decay. Drainage is especially needed in the western part of the county.

GEOLOGICAL STRUCTURE.

The Niagara limestone underlies a tier of townships along the western side of the county, spreading to the east so as to include the village of Marseilles. The western boundary of the Lower Corniferous enters the county from the north, about two miles east of Mexico, passes through Bellevernon and Little Sandusky, and leaves the county in Sec. 11, Pitt township. Hence the most of the county, which is specially characterized by its flat surface, is underlain by the Waterlime formation. It is necessary to say, however, that the western central portions of the county are entirely without rocky outcrops, and it may be that the Niagara underlies more area than has been ascribed to it; also that the boundary between the Waterlime and the Corniferous, as above located, is to a certain extent conjectural.

The *Niagara limestone* has, near Carey, an unusual and somewhat remarkable exposure. The surface of the country for many miles in every direction is flat, without exposure of rock. At this point the Niagara swells up suddenly in two separate mounds or ridges, which rise so obtrusively that the drift has been in many places entirely denuded. They rise to the height of forty to fifty feet. They are each about five miles long, and are so situated toward each other, and in relation to the direction of the natural drainage, that they enclose the marsh known as Big Spring Prairie. They are distinguished as the *North Ridge* and the *West Ridge.* The included prairie is of the shape of a horse shoe, the toe turned a little east of north, the West Ridge filling in the bow. It is usually about a mile wide, with a length of ten miles. It is drained in opposite directions. Spring Run drains it into the Sandusky river, and a stream known as "the outlet" drains it into the Blanchard. The soil is so wet that it is at present impossible to till it. Good progress has, however, been made in draining some portions, which now produce corn of prodigious growth. The descent to the prairie from the north or from the west, so as not to be intercepted by either of the limestone ridges, is very gradual, even unobservable. The soil changes imperceptibly from a more or less gravelly clay to a fine, tough clay; then by the addition of vegetable matter the surface soil becomes black and moist, and all vegetation disappears except grasses and sedges. Efforts were made to ascer-

tain the thickness of this black muck, but no result was obtained other than the fact that while it exceeds eight feet in some places, it is usually but four or five. It is thin about the margin of the marsh, and seems to be generally underlain by a tough, blue clay, often so calcareous as to constitute a marl. This blue clay is sometimes itself overlain by a bed of quicksand. Within the muck the horns of elk are said to have been found, and logs several feet in diameter. Along the south margin of the prairie, within the bow, there is considerable sand, as if the deposit of a lake shore. Within the bow of the prairie there is also considerable flat land not marshy, the surface rising very gently toward the south for the distance of nearly a mile, when the west ridge rises suddenly to the height of nearly fifty feet. The prairie is crossed by three public roads. These are constructed by throwing together the dirt from two parallel ditches, on which is placed first corduroy, and afterward, when repairs are needed, stone is hauled from the ridges, giving the road a rough macadamizing. Many months in the year the prairie is covered with water, and it is only in the driest months that cattle venture on it for grazing. Within it are sometimes little undulations or hillocks, on which grow bunches of shrubs and large herbs. The annexed figure shows the position of the prairie and the shape of the ridges.



MAP OF BIG SPRING PRAIRIE.

The rock here exposed has been found to contain characteristic Niagara fossils only in the North Ridge. There are no perpendicular sections of the bedding, except in small quarries on the slopes of the ridges near their bases. In these openings the stone appears very different from that seen in bare places higher up the ridges and on their summits, and the dip is uniformly toward the low ground, whatever the position of the quarry.

The quarry of Mr. Samuel Shaupt, situated on the western slope of the west ridge, about three miles from Carey, shows the rock dipping about fifteen or eighteen degrees toward the south-west, that is, toward the nearest low ground. It is in thin, fragile beds, of a light drab or buff color, porous, and soft under the hammer, showing no distinguishable fossils.

In the quarry of Mr. Thomas Shepherd, N.E. ¼ Sec. 11, Ridge township, about a mile north-west of Mr. Shaupt's, the following section is exposed from above; dip six or eight degrees S.W.

No. 1.	Beds thin, and so carious they can hardly be lifted; in even sheets of a buff color, sometimes reduced to sand by the weather.......		10 in.
No. 2.	Beds three to eight inches; vesicular; of a buff color; easily worked..........	4 ft.	
No. 3.	Irregularly bedded; lenticular or massive; buff color; carious; with traces of fossils..........	2 ft.	
	Total	6 ft.	10 in.

Mr. F. J. Werlow's quarry, N.E. ¼ Sec. 16, Crawford, is in the same kind of stone, but it is so far removed from the ridge that the beds have not been tilted by it. They lie horizontal, or with a very slight inclination S.W. The rock is here very near the surface. The same is true at Carey, where it is sometimes reached in digging post-holes for fences.

The quarry of Mr. Jonas Huffman is in the west slope of the north ridge, situated N.W ¼ Sec. 4, Crawford township, and shows the following descending section. Dip toward the west 10°. The rock here is overlain by about two feet of drift and loose fragments.

No. 1.	Thin beds; light drab; weathering buff; porous like a very fine sponge. Beds two to four inches without fossils	2 ft.
No. 2.	Confused and lenticular in the bedding, with larger pores or cavities, sometimes filled with calcite; fossiliferous, showing two species of bivalves, Cyathophylloids and Favositoids..........	2 ft.
No. 3.	Hard; close-grained; light drab; beds four to eight inches. The close-grained texture sometimes occurs irregularly through the mass, and has a bluish tint	2 ft.

Mr. William Divle's quarry, at Springville, in Seneca county, is near the northern extremity of the north ridge, and on the western slope. The stone is the same as Mr. Shaupt's and Mr. Shepherd's on the west ridge. It contains no fossils. Opened about four feet. Dip W.

Mr. Peter Kibbler's quarry, also at Springville, affords a slight exposure of the same kind of stone, with a gentle dip W., *i. e.* toward the prairie. The stone here seems a little more firm, but is generally porous,

with fine cavities; fossils wanting or so absorbed as to be undistinguishable. The color is a light drab, varying to buff, and also to gray, especially when thrown out in piles. The stone is not handsome, the beds being uneven and containing some white chert.

At Mr. David Smith's quarry, N. E. ¼ Sec. 3, Amanda, Hancock county, the stone is buff, porous, and in thin beds about two inches in thickness. No visible fossils except vernicular markings. This quarry is situated on the west flank of the west ridge, and the beds dip S.W. Exposed, 4 ft. 10 in.

Exposures on the north ridge, in the eastern part of Sec. 4, Crawford township, show a dip easterly, with the slope of the ground.

Stone thrown out from these quarries becomes a light buff, sometimes almost white, under the weather, and although not of a durable quality, it has been considerably used in ordinary walls and foundations.

In passing over the ridges, which are occupied by good farms, stones are often seen gathered from the fields and deposited in piles or in the corners of the fences, or laid up in walls. They consist of fragments from the underlying rock, and of northern bowlders, the former greatly predominating. Along the road the rock is frequently seen bare, and as already remarked, it is different, lithologically, from that seen in the foregoing quarries. It is most frequently a dark drab or brown, hard, crystalline rock, apparently in a rough, massive condition, containing cavities sometimes two or three inches in diameter. It nowhere appears in even beds. It is rarely vesicular like the stone seen in the quarries described, but contains large cavities, irregularly scattered through it. The color is sometimes a bluish drab, and it not unfrequently shows obscure traces of fossil remains. Surface fragments scattered over the eastern projection of the north ridge afford such fossils as *Pentamerus* (*galeatus?*) *Megalamus Canadensis*, Hall, *Platyostoma Niagarense*, *Favosites Niagarensis*, and a species of Cyathophylloid coral, with characters sufficiently definite for identification. [The following were identified with various degrees of certainty: *Pleurotomaria Elora*, Bill? *Murchisonia* (*bellicincta*, Hall? only an impression,) *Atrypa nodostriata?* (impression) *Trimarella*, sp? (common as casts), *Pentamerus oblongus* (cast). Impression of a handsome crinoid calyx. *Cyclonema sp? Favosites*, (with fine cells), an Orthoceratite and *Atrypa sulcata?* The last is very common, and occurs almost entirely as casts. Another bivalve, which appears like *Atrypa reticularis*, is very common as impressions. These occur sometimes in rock otherwise compact and solid, or they may be so numerous as to make the rock porous and loose, the interior of the shell being entirely wanting.]

The surface fragments furnishing these fossils are, however, more vesicular and lighter colored than the stone usually seen scattered over the surface of the ridges. They have the lithological characters of that phase of the Niagara seen in the Sandusky river at Tiffin, Seneca county, and at Genoa, in Ottawa county. In the N. E. ¼ Sec. 32, Crawford township, a ridge may be seen of the same kind of stone as those north of Carey, running north and south, visible about one-half mile, slightly exposed on land of Joseph Paul.

It would seem as if the conditions of the ocean's bed, in which the Niagara was formed, were not uniform. While regular strata were being deposited in a wide area, including portions of Seneca and Hancock counties, without disturbance or contortions, a concretionary and crystallizing force sprang into operation in the N. W. corner of Wyandot county, which, working from below, caused the even beds of deposition to swell upward or over the growing mass or masses. In some cases, it aided in the preservation of fossil remains; in others, it hastened their absorption into the mass of the rock. This is a peculiarity of rock formation not confined to the Niagara, but is displayed conspicuously in the Waterlimestone above, and it has been seen in the Lower Corniferous. When the lapse of time brings such hardened masses into contact with the erosions of ice and water, they cause the prominent features of the landscape, by the removal of the more destructible parts about them. Such may be the explanation ot the remarkable ridges about Carey, the even, friable beds seen in the quarries about their flanks having once been continuous over their summits, but, unable to resist the forces of the glacial epoch, were denuded down to the more enduring rock.

Within these ridges are several caves, the entrances to which are small and have been accidentally discovered, sometimes by men plowing in the field. One particularly, on Mr. Charles Zook's farm, N. W. ¼ Sec. 2, Ridge township, is described as having a perpendicular descent of sixty-five feet, to a stream of water which is also very deep, and separates one apartment by a narrow passage from another. The entrance is about five feet across, and the sides are of rock.

The Niagara in the south-west corner of the county, rises rapidly in the same way from below the Waterlime which lies to the north, the dip being N. E., and to the amount of twenty-five degrees, along sections 18 and 13, near the county line. It here appears as a thick-bedded, gray, and crystalline limestone. It also shows in the Tymochtee creek, at the village of Marseilles, in a characteristic surface exposure. About five feet of thick, hard beds may be seen along the creek, lying nearly horizontal, or with a very slight dip S. S. W. It is slightly porous and fos-

siliferous. It is sometimes blotched with blue and drab. These are the beds that rise so rapidly about a mile further south, forming a little ridge or brow of prominent land facing north. On this brow is situated the residence of Mr. Socrates Hartle. The rock is shown in the excavation for his cellar about the center of Sec. 13, (west of the village,) in Marseilles township; also, in a ditch by the roadside, in Sec. 18, about sixty rods east of Mr. Hartle's house, where the rapidity of the current of water has cleaned off the smoothed and striated rock in a handsome exposure. A little stream, locally known as Little Tymochtee creek, makes eastward along the north side of this brow of land, and on Sec. 13, less than a quarter of a mile north of Mr. Hartle's house, and perhaps thirty feet *below* the Niagara outcrop near it, the blue, slaty beds of the Waterlime may be seen in this creek.

In the S. E. ¼ Sec. 13, (S. W. of the village,) Marseilles township, Mr. M. V. Toner has a quarry in the Niagara. The beds here are three to six inches in thickness. The stone is rather firm, though somewhat porous. It is used for quicklime and for general building purposes.

On the N. W. ¼ of the same section, land of Miss Addie Terry, the Niagara has been a little worked for quicklime; dip N.

S. E. ¼ Sec. 11, (W. of the village,) Marseilles township, D. Heckathorn burns lime from the Niagara; dip north; beds about four inches. Within forty rods north of Mr. Heckathorn's quarry, the Waterlime appears in the Little Tymochtee creek.

N.E. ¼ Sec. 11, (W. of the village,) Marseilles township, H. H. Carey burns lime and supplies building stone from the Niagara; beds three to five inches; dip E.; exposed eighteen inches.

N.E. ¼ Sec. 9, (W. of village,) Marseilles township, Mr. Charles Norris burns lime from the Niagara. The creek here furnishes considerable exposure.

S.E. ¼ Sec. 11, (W. of the village,) Marseilles township, Michael Keckler has a small opening in the Niagara.

The *Salina* was nowhere observed in Wyandot county.

The *Waterlime formation*, which in counties further north presents three distinct, general lithological characters, in Wyandot county is mainly reduced to one. That aspect of the Waterlime designated "phase No. 3" on a former page, passes, with the addition of much bituminous matter, into a thin-bedded, even slaty, condition, which, first black, weathers blue on the sides of the bedding, or lastly a chocolate color, while the fractured edge is a very dark drab. Throughout the county it is known in this condition as "blue slate." When the bituminous matter is more

evenly distributed through the rock, instead of being confined to the thin partings, the beds are thicker, and of a blue color.

The principal outcrop of the Waterlime within the county is along the left bank of the Tymochtee creek, in sections 27 and 34, in Crawford township. The banks of the creek expose perpendicular sections of four to eight feet of these thin beds. The dip being continuously toward the south-west, a connected section of 84 feet 10 inches may be made out as follows, in descending order :

Section of the Waterlime in the banks of the Tymochtee Creek, Secs. 27 *and* 34, *Crawford, Wyandot County.*

No. 1.	Thin, (1 inch) dark-drab, brittle beds	1 ft.	
No. 2.	Beds two to three inches; lenticular; light-drab; weathering ashen; with *Leperditia alta*	2 ft.	6 in.
No. 3.	Light-drab beds, weathering ashen; two to six inches	2 ft.	
No. 4.	Drab, slaty beds, with frequent bituminous films; deep fracture sometimes blue-drab; beds half inch thick; blue color rarely seen; the equivalent of the stone of Carey's quarry	24 ft.	
No. 5.	Beds two to four inches; drab; compact and fine-grained; showing no blue; like the stone in June's quarry, Fremont	15 ft.	
No. 6.	Beds thin (1 to 4 inches); drab; regular; fine-grained; compact; showing no blue or chocolate; on a deep fracture bluish drab, or blue	12 ft.	
No. 7.	Drab, slaty beds; separated by brown bituminous films; above the beds are thicker but more lenticular	10 ft.	
No. 8.	Drab; fine-grained; slaty with bituminous films that weather blue. Some beds are four inches, but without long horizontal continuance	4 ft.	
No. 9.	Earthy, slaty beds, weathering blue and chocolate on the sides, which are coated with bituminous films. The broken edges of the bedding are dark-drab, sometimes with irregular spots of light-blue	10 ft.	
No. 10.	Vesicular and carious; coarse, ungainly; of a dark-drab color; with traces of fossils; mostly hid from observation, but apparently without horizontal continuance	1 ft.	6 in.
No. 11.	One bed; fine-grained; drab		4 in.
No. 12.	Beds one-fourth inch; slaty; drab; with blue films	1 ft.	
No. 13.	Drab, lenticular beds of two inches; sometimes bulging and then harder, or in regular courses of two to four inches	1 ft.	6 in.
	Total exposed	84 ft.	10 in.

Nos. 7, 8 and 9 have very much the same general lithological *facies*, and may be appropriately included in the general designation of *Tymochtee Slate*. The beds are homogeneous, tough, thin, sometimes having so much bituminous matter as to appear like the great *Black Slate*. The

thinnest beds are, however, streaked with alternations of dark drab, and a bituminous brown. When wet the brown is almost black, but when dry and weathered it assumes a blue color, and if long weathered it becomes chocolate. There are among these occasional patches of thicker, even, drab beds, which finally become so persistent, upward, as to require a special designation.

Mr. Donald M. Carey has a quarry in these thin, blue beds (Nos. 2, 3 and 4) on Sec. 27, which has acquired considerable notoriety for the large, smooth slabs or flagging it affords. Some of the thicker beds furnish also a handsome and useful stone for building. The dip is toward the S.S.W., exposure about twelve feet perpendicular. The stone here shows the characteristic *Leperditia alta*. The quarry is in the old river bank, or hardpan terrace, about forty rods from the stream.

This aspect of the Waterlime is seen in the following places in Wyandot county:

S.W. ¼ Sec. 16, Crane township. At the "Indian Mill" these blue flags have been taken out of the bed of the Sandusky and used for foundations for the mill. But in the construction of the bridge at the same place, the stone used is said to have come from Leesville, Crawford county.

Sec. 21, Crane township. At Carter's dam, in the Sandusky river, Mr. Samuel Strasser has opened the Waterlime. The stone is in irregular thick and thin beds. When freshly quarried it is blue-drab, and of a fine grain. Exposed a short time to the weather the whole pile becomes a bright blue. The fracture of the beds, however, becomes a much more ashen or drab-blue than the sides of the bedding. The dip is W.

Downward Section at Strasser's Quarry.

No. 1.	Very irregular and distorted; beds six to twenty-four inches; firm	3 ft.
No. 2.	Beds one to three inches; fine-grained; lenticular	3 ft.
No. 3.	Beds six to twelve inches; hard and fine-grained	3 ft.
	Total exposed	9 ft.

About thirty rods east of Strasser's quarry, in the bed of the Sandusky, blue flagging is taken out like that of Mr. Carey's quarry on the Tymochtee creek, except that here the blue color pervades the whole mass. Fragments of this, when very bituminous and jointed, come out in long tapering pieces. These flags show a fossil which appears like a species of *Modiolopsis*.

S.W ¼ Sec. 22, Crane township. In the bed of Rock run, a fine-grained blue stone is quarried and used for foundations. It weathers a drab

color to the depth of a half inch, or an inch, all over the outside. One bed only of six inches is exposed.

N.W. ¼ Sec. 27, Crane township. Along the bed of Rock run the Waterlime is abundantly exposed, with a general dip S.E., changing to W. at the west end of the outcrop. Mr. Peter Wynandy here burns lime and sells stone.

Section at Wynandy's Quarry, in descending order.

No. 1.	Irregular drab beds, without showing blue color; two to four inches..	3 ft.
	[Separated from No. 2 by an interval of only occasional exposure of rock, apparently the same as No. 1, with dip in the same direction]........	15 ft. ?
No. 2.	Drab beds; more regular; of two to four inches; used for quicklime; separated by brown bituminous films, which, when freshly taken out are more blue. The stone itself, especially in some of the thin bituminous layers (or films), is occasionally tinged with blue..........	4 ft.
	[Separated from No. 3 by an estimated interval of thirty feet, in which there are occasional exposures, showing the same dip and character of rock as No. 2]........	30 ft. ?
No. 3.	This only differs from Nos. 1 and 2 by the blue color of the freshly quarried stone. It lies also, perhaps, in evener beds, and furnishes large, handsome, blue blocks, the thickest of which is not over six inches. These thick beds have every conceivable alternation with thinner, more bituminous beds, which are also sometimes so thick as to constitute a bituminous shale, but are usually only a tough slate........	5 ft.
	Total exposure........	57 ft. ?

The change of color from blue to drab is very noticeable in the stone quarried from No. 3. Beds which certainly cannot have been fractured more than a few months, were seen to have already acquired a coating of drab one-eighth to one-fourth of an inch thick *over the fractured surface.* The layers themselves, before quarrying, are sometimes one-half to two-thirds drab, with a blue streak through the center. It would seem as if the drab were entirely an acquired color, and that, perhaps, the whole Waterlime was at first a blue rock. The access of air or aerated water seems to cause the change. The fact that the lower, regular beds (as at this quarry), shut off the percolations of water through the rock, may account for the longer preservation of the blue. Whenever the beds are lenticular or irregular, or are so situated that the atmosphere finds free access to them, they are drab. They are seen to be blue only when deep-seated or lying very true.

East side of Sec. 28, Tymochtee township. The Tymochtee slate is

seen in the bed of the Sandusky at Haman's mill. Handsome flags about two inches thick are taken out.

Sec. 22, Pitt township. Mr. James Anderson's quarry shows the following descending section in the bank of the Sandusky:

No. 1.	Bituminous; dark drab or brown; earthy and carious; in one vesicular bed. (The equivalent of No. 10 in the foregoing "section of the Tymochtee slate")	10 in.
No. 2.	Very hard; almost flinty, irregular beds of one-fourth inch to two inches; brown and blue on fracture; sometimes cemented so as to appear massive; with cavities containing loose, disintegrated material like much of No. 1	5 ft.
	Total exposed	5 ft. 10 in.

When No. 1 is constantly wet it is dark brown, but in the weather it becomes light brown. There are sometimes bituminous films visible on a fractured edge; no fossils.

S.W. ¼ Sec. 10, Pitt township, Mrs. Rebecca Smith owns a quarry in the Sandusky, from which a fine-grained, even bedded, blue stone, is taken, which weathers an ashen color. Here are some handsome beds, six to eight inches thick, affording a fine building material. Dip S.E.

At various other points in Pitt township, the same features of the Waterlime may be seen. No reliable estimate can be made of the thickness exposed, or of their relative places in the formation, the outcrops are so isolated, and show so nearly the same characters. The same stone is quarried in the river at Upper Sandusky, by Mr. William Frederick.

In Sec. 17, Crawford township, Mr. George Mulholland, and on Sec. 24, Messrs. Mitten & O'Brien, have quarries in the Waterlime. The stone from these openings is in thick beds, much like the gray, hard beds of the "quarry No. 3," at Tiffin.

The *Lower Corniferous* may be seen in interrupted outcrop along the Sycamore creek, from Benton, in Crawford county, to Sec. 18, in Sycamore township, Wyandot county. Through the whole of this distance it is so hid by drift that no reliable section can be obtained. It is of the coarse-grained, thick-bedded, harsh and magnesian type, until, just within Sec. 17, Sycamore, the character of the rock changes. It assumes very much the aspect of the drab, thin-bedded Waterlime. A little farther down the creek, the soft, thick beds of the Lower Corniferous return. Further still, there is another similar change to a fine-grained, compact, light-blue stone without fossils. This character continues through the most of Sec. 27, and some in Sec. 21, evinced, not often by the rock *in situ*, but by the angular, bluish, fine-grained pieces in the stream. This member of the Lower Corniferous was also seen near Mel-

more, in Seneca county. No opportunity has been afforded to ascertain its thickness, but judging from the superficial exposure, it may have a thickness of thirty or even fifty feet. In the N.W. ¼ Sec. 21, Sycamore, about eighteen inches of similar compact blue limestone may be seen in the creek, underlain by a blue shale which crumbles conchoidally, and shows spots of darker blue or purple. It is sometimes quite rock-like, yet when long weathered it crumbles. Its thickness cannot be stated, though there cannot be less than ten feet, judging from the distance it occupies the bed of the creek. On Sec. 18, of the same township, a thick-bedded, even-grained rock, harsh like a sandstone, is slightly exposed. It is gray, without visible fossils, and weathers buff. It is impossible to give its dip, thickness, or relation to the shale just mentioned. It probably lies below that. Near the same place, land of Andrew Bretz, there are also large fragments of a fragile, bituminous, crinoidal limestone, seen in the bed of the creek.

In Pitt township, S. W. ¼ Sec. 25, on the land of Jacob Brewer, the Lower Corniferous is slightly exposed in the upper bank of the Sandusky river. The rock consists almost entirely of the coral *Cœnostroma monticulifera, Win.* Only a thickness of about a foot can be seen *in situ*, but a mass of two feet thickness is tilted up so as to present the edges of the beds in a perpendicular position.

THE DRIFT.

Wherever sections were observed throughout the county, the drift shows, as in counties further north, the two usual colors. The first is light brown or ashen, and extends downward about twelve feet. It may be stratified or entirely unstratified, and forms the soil where it has not been covered with alluvial or marshy accumulations. Its color alone distinguishes it from the underlying blue, or Erie clay. They both contain bowlders that show glacial action. On Sec. 24, Crawford township, the lower member was seen exposed 27 ft. 4 in. in the bank of Tymochtee creek, embracing beds of gravel and sand. The upper, overlying, was twelve feet, and entirely unassorted; yet on Sec. 18, Tymochtee township, both are more or less stratified, as in the following diagram. No two sections of this bank would be the same. The greatest uniformity in the order of alternation is in the upper part. The blue hardpan sometimes extends upward quite to the brown clays and sands, and in one case, the whole bank consists of hardpan, the upper portion having the brown color.

The following perpendicular section was taken. It will convey an

idea of the general character of the bank, and of the drift in Wyandot county.

No. 1.	Fine, crumbling, brown clay, assorted	4 ft.	
No. 2.	Fine, compact, yellow sand		8 in.
No. 3.	Brown, sandy clay	1 ft.	
No. 4.	Fine, crumbling, brown clay		6 in.
No. 5.	Brown, sandy clay, and fine, yellow sand, in irregular beds	1 ft.	4 in.
No. 6.	Fine, yellow sand	1 ft.	4 in.
No. 7.	Clean, fine sand, with many limestone pebbles, and fragments of black slate	2 ft.	
No. 8.	Rusty sand		8 in.
No. 9.	Clean, blue sand; water-bearing		3 in.
No. 10.	Compact, fine, brown clay; assorted [To this point the brown color prevails.]		6 in.
No. 11.	*a.* Assorted, fine, blue clay *b.* Sand in oblique stratification; changing to gravel *c.* Blue clay; assorted *d.* Sand and clay; blue *e.* A bed of about three feet of sand, the strata standing nearly perpendicular; with alternate streaks of blue and white sand *f.* Fine, blue, assorted clay	5 to 6 ft.	
No. 12.	Blue hardpan, containing gravel-stones, pebbles and scratched bowlders. Near the bottom is a bed of very fine blue clay, of at least eight inches, perfectly assorted and free from pebbles. Below it, however, are several feet of hardpan; about	25 ft.	

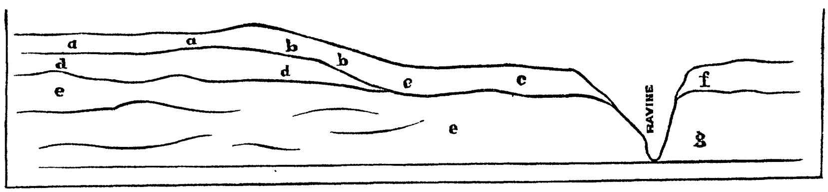


Diagram of the front view of the bank of the Tymochtee creek, showing the general superposition of the principal parts of the foregoing section. In the bed of the creek the Waterlime is in outcrop. (Figure reduced for wood-cut.)

EXPLANATION OF FIGURE.

a. Brown clay and sand; stratified.
b. Brown hardpan.
c. Stratified brown clay.
d. Stratified blue clay and sand.
e. Fine blue clay and blue hardpan.
f. Brown clay.
g. Blue clay.
h. *Debris;* bowlders and slides.

On the opposite side of the creek this bank is entirely wanting. There is a bank of a trifle over twelve feet, composed of agglutinated, rusty sand, without gravel or bowlders, at the base of which, near the water, is a bed of vegetable remains containing some pretty large limbs and numerous branches of wood. Such deposits are common in the alluvial bottoms bordering the streams. There is a gradual ascent from the level of this bank to the height of the bank on the opposite side of the river, attaining that elevation in a distance of forty rods.

MATERIAL RESOURCES.

As already remarked of other counties in north-western Ohio, the chief source of material wealth in Wyandot county lies in its rich and exhaustless soil. The streams are generally too small or too sluggish to be reliable for water-powers. The rocks themselves are not known to possess any deposits of valuable minerals. They will serve for common use in building, and will make an excellent quicklime. There is reason to believe, also, that the Waterlime, when having the characters seen in the quarry of Mrs. Smith, Sec. 10, Pitt township, will afford a cement of hydraulic properties.

Good brick of a red color are made in different places in the county from the surface of the drift. Such establishments are owned at Upper Sandusky by Jacob Gottfried and brother, and by Ulrich and McAfee; also on the S.E. ¼ Sec. 11, Salem, on the Infirmary Farm, by Jacob Ulrich. Sand for mortar is easily obtained from the numerous natural sections of the drift along the drainage valleys. A sand bank at Upper Sandusky was observed to underlie a deposit of eight feet of brown hardpan, and was excavated to the depth of ten feet. The layers of sand lay nearly horizontal.

CHAPTER XXIX.

GEOLOGY OF MARION COUNTY.

SITUATION AND AREA.

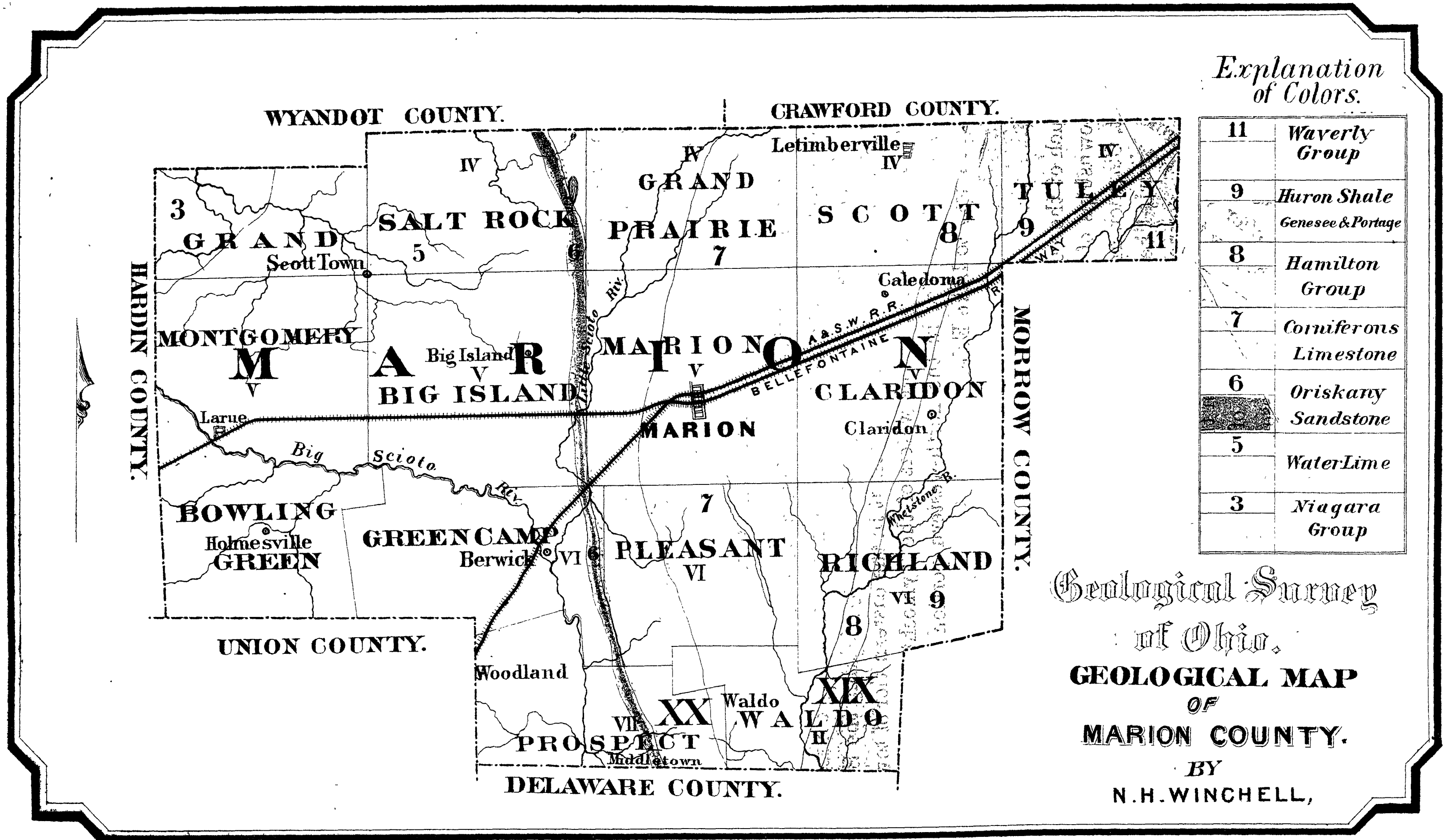
Marion county lies on the broad water-shed between the Ohio river and Lake Erie, about fifty miles south of the west end of that lake. It comprises about eleven towns. It is immediately south of Wyandot and Crawford counties. It has Morrow on the east, Delaware and Union on the south, and Hardin on the west.

NATURAL DRAINAGE.

It contains no large rivers. The Scioto, which enters it from the west, is the largest, and leaves it at Middletown in a southerly course. The Little Scioto traverses the county about midway, joining the Scioto at Berwick. The Whetstone also crosses it in the eastern tier of townships in a southerly direction. The waters of the Tymochtee and Little Sandusky take their rise in the north-western portion of the county, and find their way to Lake Erie.

SURFACE FEATURES AND SOIL.

Much of the county is flat, and has a black prairie soil, especially in the townships of Bowling Green, Big Island, Salt Rock, Grand Prairie, Scott, Claridon and the western part of Marion. The streams that cross these prairie-like tracts, are but four to six feet below the level of the land, and in time of freshet probably inundate considerable areas. There are, however, sudden changes in the character of the surface, even in the midst of the prairies. Mounds of the unmodified hardpan still project above the general surface. These have a rolling contour, and an ashen clayey soil. They are generally covered with forest, while the prairies



STROBRIDGE & CO. LITH. CIN. O

are treeless. The remaining portions of the county, namely, the townships of Grand, the northern portion of Montgomery, Greencamp, Pleasant, Richland, Tully, and the eastern part of Marion, are on the old drift surface, and have, with an undulating or rolling outline, a soil of brown or ashen clay, containing pebbles and bowlders.

GEOLOGICAL STRUCTURE.

The geological range of Marion county is from the Niagara to the Waverly, being greater than that of any other county in the State. It thus contains, approximately:*

Waverly sandstone	140 ft. ?
Huron shale (Black slate)	250 ft.
Hamilton limestone	20 ft.
Upper Corniferous	50 ft.
Lower Corniferous	150 ft.
Oriskany sandstone	20 ft.
Water limestone	100 ft.
Niagara limestone	40 ft.
Total	780 ft.

The Niagara limestone, the lowest in the scale, is found in the northwestern part of the county, and is followed toward the east by the higher members in the order above given, the general dip of the whole being in that direction. The Waterlime occupies the most of the townships of Salt Rock, Big Island, Greencamp, Montgomery and Prospect, and all of Bowling Green. The Lower Corniferous strikes across the western side of Grand Prairie and Marion townships, touching Pleasant and Prospect townships east of the Scioto river. The Upper Corniferous underlies the remainder of Grand Prairie, Marion, Pleasant and Prospect townships, and the western portions of Scott, Claridon, Richland and Waldo. The Hamilton occupies a narrow belt just on the east of the Upper Corniferous. The Black slate underlies the eastern portions of Waldo, Richland, Claridon, and most of Tully townships. The Waverly is found only in the eastern part of Tully. Of these, the Oriskany and the Lower Corniferous have not been seen in outcrop in the county, owing to the unbroken mask of the drift deposits, and the other formations offer very meager opportunities for learning their characters. It is only by tracing their

* Since this was written, Prof. Orton's Report on the Geology of Highland County has been published. He reports that county as ranging from the Lower Silurian to the Carboniferous, which exceeds Marion in range of time, but with the absence of three members of the scale—the Oriskany, Corniferous and Hamilton.

lines of outcrop from other counties where they afford better facilities for observation, that their presence and their contents in Marion county can be asserted by the geologist.

The *Niagara* was examined in the following places in Grand township:

S.E. Sec. ¼ 19, where Jeremiah Winslow has burned a little quicklime. Dip S.E.

N.E. ¼ Sec. 19. A small creek which flows north-easterly across this section into the Little Tymochtee creek, lies immediately on the hard, gray Niagara, for the distance of over half a mile, on land belonging mostly to Mr. S. Hartle. Formerly a great deal of lime was burned from the rock along this creek. The dip is to the N.E., but toward the most westerly point of exposure, the surface of the rock presents sudden changes of dip, disappearing with a dip W.

The *Waterlime* is only seen in the bed of the Scioto at Middletown, near the southern border of the county. At that place, and about two miles further south, in Delaware county, also in the bed of the Scioto, it appears as an even bedded drab rock, bluish on the laminations, and blotched throughout with blue and drab. The beds are two to four inches thick, but sometimes not more than an inch; and some blocks are ten inches thick. The blue and drab colors vary and interchange in all shapes and directions, without reference to the bedding, except that it is not uncommon to see a drab surface to the depth of one-half inch to an inch and a half, with a blue strip through the middle. The surfaces of the beds are diversified with mud cracks, and separated by bituminous films. The stone is slightly vesicular, with small cavities, yet for the most part firm and apparently compact. It is a handsome and useful building material, comparing favorably with the Upper Corniferous for all uses.

The *Upper Corniferous*, in the township of Grand Prairie, is worked quite extensively on N.W. ¼ Sec. 26, by Mr. James Dawson. Here the beds dip slightly toward the east; perpendicular exposure about twelve feet, facing the west.

In this immediate neighborhood are the following quarries, also in the Upper Corniferous:

S.W. ¼ Sec. 23. By Adam Coonrod.
S.W. ¼ Sec. 23. By Philip Rhetter.
N.W. ¼ Sec. 26. By heirs of Landy Shoots.
N.E. ¼ Sec. 27. By Eli Powell.

At Marion, the Upper Corniferous is extensively wrought by Seas & Haberman, and by Franklin Swaigler, who have, in adjoining quarries, an exposure of about twelve feet of perpendicular bedding. Dip E. Sim-

ilar beds are also wrought by John Ballentine, by Joshua Finch, and by Nathan Powers.

S.W. ¼ Sec. 10, Marion township, Mr. Elijah Hardy burns lime from the Upper Corniferous.

S.E. ¼ Sec. 9, Marion township, Mr. Leonard Reiver has taken out some stone from the Upper Corniferous.

Four and a half miles south of Marion, in Pleasant township, Mr. John Owen burns and ships at Marion considerable quantities of quicklime. Sells building stone on the ground at fifty cents per ton. Dip E.

In Richland township, the Upper Corniferous appears in the Whetstone on Secs. 30 and 19, and is quarried on the land of Daniel Oborn; also on the land of Mr. George King, N.E. ¼ Sec. 20.

The *Hamilton.* In the bed of the Whetstone, about a mile below the village of Waldo, may be seen a very hard, blue, pyritiferous limestone, in beds of eight to twelve inches, which is believed to belong to the Hamilton, although there is not sufficient exposure within the county to determine its horizon. This would furnish a fine building stone, were it not for the abundance of pyrites crystals contained in the rock. After a few months' exposure to the weather, these will inevitably change to the yellow peroxyd of iron, the rusty drippings of which present an offense to the eye, and soil the beauty of any wall.

The *Huron Shale* is popularly known as "the black slate." At various places in the bed and banks of the Whetstone river, in the townships of Richland, Claridon and Tully, it finds characteristic exposure. It may be seen N.E. ¼ Sec. 16, Richland township, where it is in thin, brittle sheets, and rises several feet along the bank of the stream. It holds large, concretionary masses of a coarse black limestone. These are very hard, and appear arenaceous at the center, with a band of more calcareous and crystalline material round the outside. They sometimes exceed four feet in diameter. Globular masses of crystalline pyrites are also common, often several inches in diameter. The black slate may also be seen in Secs. 3 and 26 of the same township, and Sec. 34 of Tully township, land of James Brown Lee. In the absence of other stone, this slate has been somewhat used for walling wells in the eastern part of the county.

The *Waverly Sandstone* is quarried to a limited extent on land of Mr. James Brown Lee, Sec. 34, Tully township. It here has a position to the west of observed exposures of the underlying Black Slate, and must be an outlier from the more extensive beds of the same stone which lie further east. Other openings are met with on Sec. 36 of the same township, and at Iberia, in Morrow county.

The Drift shows no apparent diminution in Marion county. Since its general character differs in no respect from that already described, but few points of observation will be noted. At Middletown the contents of a gravel bank were noticed to contain a great many large fragments from the Water-limestone, so arranged as to indicate not only the agency of water in rapid currents, but the direction of its flow. Some of these pieces of limestone were as much as two feet across, but usually not over two inches in thickness, and but slightly water-worn. They lay in the midst of gravel which had a stratification dipping rapidly toward the south. The limestone fragments also lay with their sides almost invariably upward, but sloping with less inclination in the same direction, similar to the arrangement of flat stones or other obstructions often seen in the bottoms of streams. It would seem as if the water, precipitated in cascades down the southern slope of the glacier, bringing such dislodged portions of the drift as fell into the current, sought to arrange the obstructions to its flow so as to offer the least resistance.

On the S.W ¼ Sec. 36, Salt Rock township, a well seventy feet in depth through drift deposits, furnished no water—dug on the premises of R. W. Messenger.

About Berwick, and a mile or two west, there are unusual numbers of bowlders, some as large as six feet in diameter. The country about is rolling, and they seem to have been embraced within the drift. In the southern part of Pleasant and Greencamp townships, especially in the vicinity of Middletown, the upper portions of the drift are very apt to contain deposits of gravel and sand, with frequent bowlders.

At Waldo, the drift is seen to consist, along the river bank, of twenty-five feet hardpan. Brown color prevails downward about fifteen feet; blue below that depth, soon becoming sandy, furnishing water. In other places, within a half-mile, the top of the drift is gravel and sand, with only a thin covering of hardpan.

MATERIAL RESOURCES.

Gravel is found in the southern part of the county, and is extensively employed in road-making. Clay, for red pottery and brick, is abundant throughout the county. Stone taken from the various quarries in the Upper Corniferous formation, serves for all purposes of building. It may be employed in the most massive as well as in all ordinary structures, having resistance sufficient to withstand any pressure needed. It is of a light blue or gray color, and when arranged properly in a building, with stone of a lighter shade, it produces a fine architectural effect. In the city of Marion it is employed in the county jail and numerous stores.

Its dark shade produces in a building the æsthetic effect of strength, age and solidity, making it specially adapted to Gothic structures.

The Black Slate has heretofore been esteemed of little or no economical value. It is due, however, to the enterprise of a citizen of Defiance, in Defiance county, Mr. E. H. Gleason, that we have the practical demonstration of the eminent hydraulic qualities of the Black Slate in Ohio. Mr. Gleason uses the lowest seventeen feet of the formation, which attains an aggregate thickness of nearly three hundred feet, with very uniform characters. We have no reason to doubt that the hydraulic property pervades the whole. Owing to the inflammable bituminous matter it contains, the slate is easily and cheaply burned, to a certain extent supplying its own fuel. Six to eight hours of red heat expel all volatile matter, leaving a lime which is easily reduced to a powder. The stone is not selected altogether promiscuously from the quarry. It is thought that the most compact and calcareous courses, which, when burned, are of a grayish or ashy purple, afford the best hydraulic cement. The more slaty and highly bituminous beds, after burning, are of a light cream color, or white with yellowish streaks and spots. Yet more than a half of the stone burned by Mr. Gleason is of the latter quality. The cement has been put to practical test in a number of ways at Defiance, and is now being employed in the abutments of an iron bridge at that place, over the Wabash and Erie canal, in connection with the Oriskany sandstone, quarried at Whitehouse, in Lucas county. Mr. Gleason employs two constant draw-kilns, and grinds the lime by steam power.* It is only necessary to add that in Marion county the base of the Black Slate strikes across the townships of Scott, Claridon, and Richland, and that its exposures along the Whetstone afford ample facilities for a similar enterprise.

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*It is due, perhaps, to the Geological Survey, to add that Mr. Gleason attributes the success of his enterprise to the suggestions and advice of members of the present Geological Corps. Other cases could be named in which the visits of the geologist have resulted in the immediate development of home products.

APPENDICES.

APPENDIX A.

TABLES ON TEMPERATURE AND RAIN FALL.

TABLE I.—CINCINNATI.

Monthly and annual Mean Temperature at Cincinnati, Ohio. Lat. 39° 6′ N., Long. 84° 29′ W. From observations taken by GEO. W. HARPER, A.M.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1856	21.9	28.	36.	60.	64.	77.8	82.3	74.	68.	58.5	44.5	31.	53.83
1857	21.5	45.4	40.4	44.	61.3	71.8	78.	77.3	68.8	56.	39.	42.	53.79
1858	42.5	30.5	44.6	57.	64.	76.	84.7	78.	70.1	59.	42.6	45.	59.83
1859	36.5	41.	54.	55.	70.9	73.1	80.4	75.	66.8	52.4	47.	27.7	57.45
1860	35.8	35.5	45.	55.5	70.3	75.	78.2	77.4	65.6	57.	40.7	31.	55.58
1861	32.	40.	42.	55.7	61.	76.	74.	76.	67.7	57.5	43.	40.	55.40
1862	34.6	33.7	42.5	54.	66.	72.	79.	79.	69.	57.6	43.	39.	55.78
1863	36.5	36.	40.	53.	67.	71.	77.5	72.	65.	49.	43.	37.	53.83
1864	28.	34.6	39.	49.7	64.	75.	79.6	76.	65.7	50.	43.6	33.	53.18
1865	24.7	35.	47.	56.	63.	77.	76.	76.	75.	54.	43.	37.	55.30
1866	31.	32.	47.	59.	61.6	72.	78.	69.	64.8	56.	44.	30.	53.70
1867	23.	39.7	36.	54.4	58.	74.	76.4	76.	70.5	55.	45.	32.8	53.40
1868	27.	31.	47.	49.	61.4	71.	82.	73.	62.	55.5	42.8	29.	52.55
1869	36.5	36.6	34.	50.9	60.6	70.7	76.	79.4	67.4	45.4	38.6	34.6	52.55
1870	33.2	33.	39.	54.4	68.	73.1	81.	77.	72.	57.7	45.	30.4	55.31
1871	34.5	36.6	49.	57.7	66.7	74.4	74.7	77.1	64.5	57.5	41.4	30.2	55.37
Means	31.20	35.54	42.65	54.07	64.24	73.74	78.61	75.76	67.68	55.50	42.88	34.98	54.67

TABLE II.—CINCINNATI.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Cincinnati, Ohio. Lat. 39° 6′ N., Long. 84° 29′ W. From observations taken by GEO. W. HARPER, A.M.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1856	1.	2.49	1.51	.73	1.23	2.24	3.43	.61	3.62	1.74	2.09	2.19	22.88
1857	.54	1.98	.76	2.73	5.53	3.09	2.50	2.92	.75	4.92	5.36	3.82	34.90
1858	2.56	1.74	1.05	4.34	8.32	5.69	3.01	7.97	.85	4.66	2.57	6.41	49.17
1859	2.58	5.92	4.38	7.53	2.32	3.22	1.24	3.79	2.10	1.28	4.46	3.75	42.57
1860	1.43	1.56	.41	5.32	3.68	1.55	7.97	.92	4.34	1.28	3.53	1.85	33.84
1861	2.68	1.81	2.08	3.88	5.91	3.80	3.62	7.10	2.93	3.77	3.62	1.10	41.30
1862	4.74	2.36	5.84	6.30	3.32	3.02	3.05	1.49	.93	.80	3.97	3.01	38.83
1863	5.55	3.05	4.37	2.13	2.84	3.11	3.21	2.99	3.10	3.85	2.05	3.80	40.05
1864	1.85	.99	.90	2.43	2.34	3.43	1.25	3.42	8.66	2.92	3.40	2.94	34.51
1865	2.45	2.43	4.40	3.89	7.72	2.59	7.77	2.26	5.76	.86	.56	3.89	44.58
1866	2.74	1.26	5.06	2.03	.94	4.44	6.94	2.75	10.55	1.85	3.06	1.98	43.60
1867	1.41	3.56	2.71	2.74	3.80	3.73	1.60	1.57	0.47	2.05	2.20	3.07	28.91
1868	3.72	.57	4.87	2.72	6.09	5.60	1.21	4.64	7.19	1.22	1.70	2.07	41.60
1869	1.60	2.51	5.06	2.87	5.93	3.60	5.36	1.20	3.20	2.75	3.30	2.46	39.84
1870	5.35	1.55	3,26	1.59	1.74	4.84	2.38	.58	.30	2.77	1.50	2.17	28.03
1871	2.34	3.53	3.57	1.23	4.66	2.02	4.30	5.22	1.08	.98	3.40	3.31	35.64
Means	2.66	2.33	3.14	3.28	4.12	3.56	3.68	3.09	3.49	2.35	2.92	2.99	37.61

TABLE III.—PORTSMOUTH.

Monthly and annual Mean Temperature at Portsmouth, Ohio. Lat. 38° 45′, *Long.* 80° 50′ *Height above the sea*, 523 *feet. From observations taken by* D. B. COTTON.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1860	35.20	37.69	46.81	57.93	69.00	71.02	78.02	73.67	65.28	57.78	42.00	33.15	55.63
1861	35.20	40.68	44.76	57.86	61.73	74.64	72.39	75.21	66.46	55.41	43.52	37.40	55.40
1862	37.12	36.57	43.46	55.37	66.94	72.60	79.10	78.65	71.82	58.07	45.22	40.46	57.11
1863	39.50	40.45	41.97	53.96	72.30	70.00	76.16	74.64	65.02	53.11	45.85	40.44	56.12
1864	33.25	38.89	43.03	52.25	64.27	71.83	77.96	76.68	68.61	52.11	47.69	36.92	55.29
1865	30.11	37.17	49.21	58.23	63.47	73.73	73.99	71.12	72.12	54.44	44.34	39.09	55.58
1866	32.90	34.48	43.17	60.06	61.09	72.38	75.95	69.37	65.94	57.13	44.87	31.55	54.07
1867	24.82	41.43	39.57	55.72	60.19	76.05	76.02	74.59	71.43	36.39	46.83	35.62	53.22
1868	29.80	34.49	50.51	48.99	61.71	71.94	80.76	72.69	64.38	54.96	44.30	31.80	53.86
1869	38.89	37.94	39.09	52.78	62.16	69.88	75.08	75.94	67.35	47.98	40.30	37.42	53.73
1870	38.00	35.79	39.96	54.15	67.69	73.01	77.94	75.09	70.35	58.91	46.08	33.35	55.86
Means	34.07	37.78	43.78	55.16	64.59	72.46	76.67	74.33	68.07	53.30	44.64	36.11	55.08

TABLE IV.—PORTSMOUTH.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Portsmouth, Ohio. Lat. 38° 45′, Long. 80° 50′. Height above the sea, 523 feet. From observations taken by D. B. COTTON.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1860	3.94	1.05	1.01	4.24	3.59	1.90	3.96	2.57	3.18	1.58	4.64	2.25	33.91
1861	3.10	2.60	1.81	5.35	5.99	2.13	1.40	5.45	3.19	3.60	5.86	1.64	42.12
1862	7.25	4.08	4.98	6.15	1.56	3.34	1.81	2.50	1.16	1.50	2.26	2.60	39.19
1863	6.22	3.48	4.43	2.01	1.34	1.76	4.32	4.15	1.52	3.16	2.14	2.24	36.77
1864	1.92	1.45	2.68	2.26	3.29	2.94	1.00	4.11	2.35	3.05	5.52	4.34	34.61
1865	2.65	3.15	5.90	3.95	10.59	4.30	6.17	2.00	6.03	1.15	1.15	6.53	53.57
1866	4.61	3.02	3.69	2.82	1.33	2.93	4.72	2.82	9.29	3.41	4.82	1.51	44.97
1867	2.95	5.96	7.11	1.37	4.64	1.46	4.34	4.32	.72	5.57	2.10	4.47	45.01
1868	1.81	.95	3.83	4.71	6.26	4.40	2.97	4.45	9.01	1.64	1.85	3.21	45.09
1869	2.83	2.52	4.57	4.22	3.86	4.70	4.20	2.21	3.48	2.28	3.82	3.16	41.85
1870	4.92	3.68	3.82	3.48	1.34	3.17	7.54	4.95	.75	2.99	2.18	2.04	40.86
Means	3.84	2.90	3.98	3.69	3.98	3.00	3.86	3.59	3.70	2.72	3.30	3.09	41.63

TABLE V.—MARIETTA.

Monthly and annual Mean Temperature at Marietta, Ohio. Lat. 39° 25′ *N., Long.* 81° *W. From observations taken by* GEO. O. HILDRETH, M.D.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1860	32.66	35.00	44.13	54.30	65.50	68.03	73.68	72.23	62.10	62.17	40.29	30.13	53.35
1861	32.33	38.20	43.00	52.70	56.39	70.25	68.17	71.00	66.00	54.89	41.33	37.00	52.60
1862	35.31	38.66	40.19	51.11	59.56	65.90	72.71	73.40	68.34	54.97	40.84	35.52	52.62
1863	34.01	35.85	37.17	48.94	62.04	66.12	73.16	73.98	62.88	49.86	43.01	35.92	51.91
1864	28.25	32.57	36.81	48.65	61.38	68.18	74.09	73.10	63.62	49.90	42.95	32.44	51.00
1865	24.22	32.69	45.76	55.12	59.92	73.64	71.70	69.77	71.30	51.32	41.38	35.98	52.73
1866	29.36	30.53	39.07	55.53	57.32	68.67	74.69	66.25	63.42	53.13	41.54	29.47	50.74
1867	20.70	38.16	36.60	52.60	54.83	70.27	71.81	71.02	67.16	52.68	42.77	31.74	50.86
1868	26.89	29.33	44.68	48.25	58.81	67.74	77.96	70.72	61.82	50.63	41.32	29.24	50.61
1869	35.37	34.79	36.31	49.55	59.47	68.05	72.16	73.06	63.62	45.49	36.55	34.36	50.73
1870	34.31	31.95	36.43	52.02	63.51	69.17	74.83	72.29	66.74	54.10	41.55	30.91	52.31
1871	33.43	35.89	47.96	55.18	61.70	70.56	71.01	73.61	61.05	54.53	40.21	29.80	52.91
Means	30.57	34.05	40.67	51.99	60.03	68.88	72.99	71.70	64.83	52.80	41.14	32.70	51.86

TABLE VI.—MARIETTA.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Marietta, Ohio. Lat. 39° 25′ N., Long. 81° W. From observations taken by Geo. O. Hildreth, M.D.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1860	3.24	1.34	1.08	5.28	2.88	2.31	5.87	4.16	3.26	4.40	4.01	2.08	39.91
1861	2.70	2.31	2.27	6.37	5.61	3.96	5.14	3.03	4.31	4.43	4.63	1.61	46.41
1862	7.37	2.81	3.39	7.67	3.78	2.52	3.52	3.64	0.28	2.57	2.05	3.07	42.71
1863	6.63	2.76	4.03	1.93	1.98	2.13	3.22	1.94	2.34	4.69	2.80	2.57	37.06
1864	1.40	2.07	4.04	3.54	4.17	2.02	1.95	7.57	3.13	2.84	3.91	4.25	40.93
1865	3.83	2.95	5.84	3.46	8.08	4.96	5.88	3.30	3.95	1.46	1.35	3.73	48.84
1866	3.94	3.44	3.91	3.87	0.94	4.56	4.51	4.15	7.70	2.94	3.52	3.74	47.26
1867	2.98	5.27	5.85	2.49	6.04	2.74	5.04	4.06	0.60	4.47	1.94	5.19	46.70
1868	2.93	1.37	5.17	4.12	4.63	3.38	6.45	4.78	10.31	1.85	2.47	2.55	50.03
1869	4.62	3.66	3.94	3.40	2.35	4.72	4.96	2.70	5.13	1.28	3.15	2.91	42.86
1870	5.28	2.93	4.86	3.91	1.83	5.13	6.37	2.89	0.93	2.18	1.89	1.96	40.18
1871	2.44	2.71	1.46	2.01	2.71	2.78	5.36	3.32	1.54	1.46	1.43	1.77	29.02
Means	3.94	2.80	3.82	4.00	3.75	3.43	4.85	3.71	3.62	2.88	2.76	2.95	42.65

Mean for 30 years, ending with 1871 .... 42.98

TABLE VII.—URBANA.

Monthly and annual Mean Temperature at Urbana, Ohio. Lat. 40° 61′ N., Long. 83° 43′ W. From observations taken by MILO G. WILLIAMS.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1852	19.94	31.33	42.04	48.98	63.22	68.28	74.81	71.65	62.70	58.60	38.70	36.04	51.36
1853	32.95	32.60	38.66	50.56	60.30	73.50	70.70	71.21	63.98	48.61	45.57	31.40	51.67
1854	29.46	35.62	43.77	50.96	62.84	70.85	77.53	74.35	70.00	55.27	38.78	30.85	53.36
1855	29.55	22.53	32.80	53.38	62.63	67.12	75.08	72.50	67.22	49.03	42.95	28.77	50.29
1856	14.39	19.32	27.34	52.52	58.81	71.73	75.05	66.66	62.10	53.35	38.28	21.93	46.79
1857	14.37	38.95	34.35	39.56	55.98	67.98	72.84	71.70	65.40	50.00	35.44	35.87	48.53
1858	36.45	22.70	38.73	49.30	59.00	73.40	73.39	71.83	64.99	55.50	35.36	37.08	51.48
1859	29.19	32.74	45.60	48.00	66.10	67.93	74.70	71.28	63.16	47.90	43.70	22.00	51.20
1860	29.11	30.61	42.14	51.62	66.23	69.77	72.73	71.68	60.90	53.50	36.70	26.23	50.95
1861	27.26	36.71	38.38	49.43	61.67	71.17	74.09	71.34	64.49	50.42	39.88	36.20	51.64
1862	29.03	28.06	37.66	50.93	61.28	66.70	73.35	72.45	66.80	54.21	39.41	33.54	51.12
1863	32.70	32.98	36.60	50.60	64.57	68.15	74.03	72.61	62.65	47.41	42.67	32.92	51.48
1864	25.11	30.30	35.73	46.84	62.60	70.25	74.52	72.56	63.12	48.48	41.09	27.71	49.88
1865	19.96	30.08	43.44	53.07	61.64	74.50	71.81	69.70	72.37	50.00	38.58	31.30	51.37
1866	25.81	26.27	34.96	55.77	58.73	69.31	75.46	65.44	61.78	53.38	40.86	26.47	49.52
1867	17.89	34.24	31.68	51.17	55.35	73.25	73.89	73.08	68.10	54.70	45.11	28.57	49.65
1868	21.75	25.09	42.61	46.66	60.26	69.58	80.48	71.45	60.46	49.39	40.42	25.70	49.49
1869	33.38	32.88	32.00	48.42	59.14	68.32	72.75	73.92	65.20	43.74	34.50	31.54	49.65
1870	29.90	29.07	35.25	53.77	65.56	70.97	76.26	73.13	68.95	54.86	40.38	26.93	52.06
1871	31.27	33.15	46.85	56.43	64.64	71.41	72.67	74.68	61.45	55.55	37.01	26.25	52.61
Means	26.47	30.26	38.37	50.40	61.52	70.22	74.31	71.66	64.79	51.69	39.78	29.86	50.70

TABLE VIII.—URBANA.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Urbana, Ohio. Lat. 40° 6′ N., Long. 83° 43′ W. From observations taken by MILO G. WILLIAMS.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sums.
1852	2.74	3.13	4.99	5.69	4.41	4.21	3.68	3.05	6.03	3.59	5.64	11.68	58.84
1853	1.79	4.01	2.53	4.42	3.06	4.72	4.16	8.44	4.16	2.49	3.67	1.75	45.20
1854	3.61	3.76	5.41	5.75	6.02	5.80	1.67	1.99	1.97	4.46	2.62	1.29	41.35
1855	3.97	1.66	3.40	2.56	6.72	10.78	6.17	1.23	8.76	3.18	5.18	3.86	57.47
1856	1.02	1.90	1.09	1.90	3.84	3.23	3.89	2.37	2.91	2.08	3.62	3.02	38.87
1857	1.16	3.20	1.85	1.94	6.41	3.05	4.23	4.63	1.84	3.27	5.65	2.64	39.77
1858	2.03	1.48	.96	3.86	7.50	5.26	3.60	4.36	1.97	1.78	3.39	4.80	40.99
1859	2.30	3.05	4.16	4.25	1.61	4.18	.80	2.20	3.35	1.26	4.69	4.66	36.53
1860	1.85	2.05	.76	6.30	1.07	3.37	6.21	3.93	2.59	2.00	2.42	3.17	35.72
1861	1.97	1.62	2.95	3.95	4.35	4.19	3.69	3.29	3.42	2.88	2.83	1.21	36.35
1862	3.01	2.47	4.83	5.10	3.70	3.20	4.02	2.33	.60	1.13	3.08	4.32	37.79
1863	6.36	3.13	2.50	1.69	3.54	1.31	2.10	1.66	3.13	3.62	3.01	4.51	36.56
1864	1.89	.55	2.33	2.31	2.21	3.82	.84	5.47	3.71	1.89	3.53	3.64	32.19
1865	1.55	1.97	4.68	6.92	4.11	5.06	4.62	6.66	5.32	1.22	.73	3.20	46.04
1866	3.39	2.25	3.51	1.36	1.59	5.54	4.74	3.57	15.88	2.41	3.27	2.11	49.62
1867	1.59	3.85	3.08	3.48	2.27	4.08	2.87	2.08	.32	2.01	2.14	4.09	31.86
1868	2.44	1.03	7.51	3.35	6.19	10.38	1.88	5.21	3.81	1.17	1.77	1.57	46.31
1869	1.50	3.40	5.73	2.43	7.09	2.49	6.52	1.01	3.32	1.89	4.21	3.12	42.71
1870	6.66	2.02	4.26	1.14	.68	3.07	2.63	2.34	.47	4.00	1.90	3.13	32.30
1871	1.55	1.85	2.74	2.84	2.00	3.65	2.45	6.48	.25	1.20	3.33	2.30	30.64
Means	2.62	2.42	3.46	3.56	3.92	4.42	3.54	3.61	3.69	2.38	3.34	3.50	40.45

TABLE IX.—CLEVELAND.

Monthly and annual Mean Temperature at Cleveland, Ohio. Lat. 41° 30′, *Long.* 81° 40.′ *From observations taken by* GUSTAVUS A. HYDE.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1860	30.26	31.40	42.24	47,24	63.22	67.42	69.66	69.19	60.81	53.51	39.40	27.19	50.13
1861	26.72	33.95	35.93	49.81	53.81	69.22	71.36	71.54	65.51	55.71	41.61	37.56	51.06
1862	28.46	27.85	34.97	48.25	57.42	64.59	74.33	74.04	67.19	56.57	41.88	36.85	51.03
1863	34.13	31.02	34.23	45.65	61.94	66.42	72.20	73.29	62.54	50.83	44.02	35.99	51.02
1864	28.71	31.93	35.93	46.63	60.26	68.57	74.97	73.17	63.13	50.38	42.62	30.11	50.53
1865	23.23	29.05	41.62	50.30	58.11	73.61	69.84	69.17	69.72	51.22	41.19	32.75	50.82
1866	26.69	27.80	33.68	51.76	54.87	68.81	74.65	65.42	60.55	52.77	41.62	27.60	48.85
1867	20.72	34.60	31.57	47.08	52.39	71.04	71.48	71.12	63.66	53.55	43.57	27.97	49.06
1868	21.49	23.15	37.15	42.48	54.59	66.11	77.70	69.24	59.69	48.29	40.26	26.26	47.20
1869	33.18	30.69	29.60	45.76	56.73	64.24	69.50	70.08	63.95	44.88	35.02	32.38	48.00
Means	27.36	30.14	35.69	47.50	57.33	68.00	72.57	70.63	63.67	51.77	41.12	31.47	49.77

TABLE X.—CLEVELAND.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Cleveland, Ohio. Lat. 41° 30′, Long. 81° 40′. From observations taken by GUSTAVUS A. HYDE.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1860	2.01	1.58	0.99	5.80	2.74	1.44	4.31	4.29	4.22	3.08	3.61	1.67	35.74
1861	1.72	1.08	2.69	4.03	3.35	1.70	1.59	3.39	3.08	3.53	4.51	1.43	32.10
1862	3.03	2.35	3.39	2.69	2.33	4.96	5.32	1.06	2.30	2.28	3.68	3.60	36.99
1863	3.87	2.87	2.85	0.98	3.07	2.24	1.65	2.06	2.63	2.53	4.02	1.99	30.76
1864	2.30	0.53	1.90	1.96	3.57	0.34	1.66	6.71	5.19	1.63	3.51	2.72	32.02
1865	1.77	1.46	2.62	2.84	2.27	3.57	3.45	1.36	4.82	2.75	0.86	3.71	31.48
1866	1.99	2.30	4.00	2.37	4.04	9.80	3.53	3.76	7.91	3.54	3.04	2.63	48.91
1867	2.34	3.15	2.73	3.21	5.02	1.81	2.72	0.88	1.38	3.56	2.87	3.16	32.83
1868	1.46	1.47	4.20	2.97	4.64	5.48	0.45	4.34	4.72	1.09	3.73	1.48	36.03
1869	1.47	3.02	3.89	2.65	3.94	3.52	3.82	1.12	6.27	2.66	3.58	3.08	39.02
Means	2.20	1.98	2.92	2.95	3.50	3.49	2.85	2.90	4.25	2.66	3.34	2.55	35.59

TABLE XI.—KELLEY'S ISLAND.

Monthly and Annual Mean Temperatures at Kelley's Island, Ohio. From observations taken by GEO. C. HUNTINGTON.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1859	....	....	....	....	....	....	....	....	....	....	43.91	25.50	....
1860	28.60	29.17	39.36	45.25	61.44	68.38	70.69	70.72	61.25	53.40	40.07	26.95	49.66
1861	27.22	32.42	34.73	46.82	53.28	68.43	70.69	71.82	65.28	55.42	41.04	35.80	50.25
1862	26.98	26.73	32.93	44.70	56.83	64.80	73.14	73.39	67.09	54.37	40.40	34.39	49.65
1863	32.36	29.00	32.00	43.03	59.92	66.51	71.42	72.16	62.46	50.14	43.07	34.37	49.72
1864	25.26	30.02	33.98	45.02	59.95	69.71	76.17	75.00	64.41	51.23	41.00	28.67	50.03
1865	23.17	28.69	38.93	48.65	59.26	74.53	71.46	71.88	72.97	53.50	42.82	31.55	51.45
1866	25.39	26.08	31.66	49.64	56.27	69.11	77.57	69.03	62.98	56.18	43.35	29.03	49.69
1867	20.70	32.80	31.14	47.06	52.44	72.39	74.02	74.92	66.82	56.65	44.92	28.92	50.23
1868	21.65	23.86	36.16	42.21	55.94	68.19	81.72	73.03	63.89	50.83	41.79	27.13	48.87
1869	33.17	30.67	29.65	44.95	57.11	67.12	73.58	74.16	69.50	47.00	....	....	....
Means..........	26.45	28.94	34.11	45.73	57.24	68.92	74.05	72.61	65.67	52.87	42.24	30.23	49.92

TABLE XII.—KELLEY'S ISLAND.

Monthly and annual quantity of Water from Rain, (and Snow reduced to Water), in inches and hundredths, at Kelley's Island. From observations taken by Geo. C. Huntington.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1859	....	....	....	....	....	....	....	....	....	....	2.47	1.95	....
1860	1.19	0.83	0.95	5.06	1.24	1.08	5.20	2.62	2.09	2.93	1.17	1.52	21.57
1861	1.27	1.01	3.38	4.19	2.13	1.32	3.69	4.34	2.52	2.09	3.00	1.11	25.04
1862	2.80	2.13	5.18	3.26	4.19	4.21	5.06	1.84	2.14	2.50	3.90	4.71	34.93
1863	3.04	2.62	1.51	1.98	2.12	3.00	1.43	1.74	1.29	2.84	3.51	2.89	23.31
1864	1.75	0.64	2.11	4.47	4.04	1.77	4.81	3.20	4.89	3.20	4.43	2.10	31.18
1865	1.27	1.53	2.04	2.65	2.46	2.77	4.54	1.75	8.23	3.11	0.43	3.26	28.37
1866	1.86	1.68	2.81	1.11	3.77	7.42	4.97	2.29	7.15	1.84	3.48	2.23	33.80
1867	1.46	3.42	1.98	3.27	5.08	1.19	3.63	0.14	0.84	1.68	1.31	2.33	21.94
1868	1.00	0.83	3.91	1.83	2.86	5.98	0.53	3.78	3.29	0.78	2.24	0.45	22.90
1869	0.71	2.67	2.45	3.22	5.11	6.07	1.39	1.50	1.99	1.93	....	....	....
Means	1.63	1.74	2.63	3.10	3.30	3.48	3.53	2.32	3.44	2.29	2.59	2.26	26.92

TABLE XIII.—HUDSON.

Monthly and annual Mean Temperature at Hudson, Ohio. Lat. 41° 14′ 43″. *Long. W. from Washington* 17 *m,* 32 *s.* 1. *West of Greenwich* 81° 25′ 48″. *From observations taken at Western Reserve College.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean for the year.
1860	27.81	29.28	39.67	45.87	64.39	66.87	69.32	70.62	59.93	51.96	38.01	25.68	49.12
1861	26.59	33.77	35.10	47.91	53.58	69.30	70.46	70.61	62.16	52.50	38.86	34.87	49.64
1862	26.69	26.36	33.85	47.54	57.73	64.02	71.51	72.43	65.04	52.60	37.81	33.39	49.08
1863	30.98	28.71	31.66	45.22	62.66	66.10	70.47	70.87	60.03	46.80	39.97	32.76	48.85
1864	25.63	28.71	32.52	44.91	59.42	68.94	73.81	74.50	60.94	48.25	39.84	27.69	48.76
1865	29.31	28.43	41.02	51.17	59.38	74.04	69.30	69.05	71.08	49.88	40.93	32.08	51.31
1866	25.47	26.94	31.17	52.67	56.33	67.97	75.17	65.22	65.07	54.07	41.74	28.03	49.15
1867	20.05	35.12	31.92	47.11	52.53	71.93	74.25	74.14	66.74	52.45	44.32	31.02	50.13
1868	25.94	36.03	33.94	39.32	63.21	73.03	79.53	72.18	61.37	49.24	48.07	26.35	50.68
1869	33.16	31.45	29.74	46.12	57.41	67.28	69.93	72.01	64.26	44.54	34.86	31.73	48.55
Means	27.16	30.48	34.06	46.78	58.66	68.95	72.38	71.16	63.66	50.23	40.44	30.36	49.53

TABLE XIV.—HUDSON.

Monthly and annual quantity of Water from Rain, and Snow reduced to Water, in inches and hundredths, at Hudson, Ohio. Lat. 41° 14′ 43″. Long. W. from Washington 17 m. 32 s. 1. W. of Greenwich 81° 25′ 48″. From observations taken at Western Reserve College.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Sum for the year.
1860	2.01	2.91	3.73	7.47	4.15	4.44	5.20	4.44	4.66	4.57	10.50	5.09	59.17
1861	3.56	4.18	3.58	8.95	6.71	2.70	3.59	4.63	3.49	2.37	3.33	1.19	48.24
1862	3.02	1.97	2.14	2.07	2.61	3.52	3.22	.85	1.98	3.38	3.57	2.90	31.20
1863	4.81	2.41	2.46	.73	1.88	1.56	2.57	4.30	.98	2.61	2.82	2.31	29.40
1864	3.94	1.23	1.81	2.83	2.45	1.49	5.30	6.93	5.95	2.10	2.20	2.94	39.12
1865	2.29	1.67	3.04	2.72	4.21	3.67	7.45	1.86	7.39	2.03	1.17	2.84	40.32
1866	.17	.84	.14	1.25	3.95	6.62	2.99	3.67	6.33	2.57	1.56	5.06	35.16
1867	3.00	2.34	2.95	1.96	2.22	1.41	1.77	.44	....	.87	2.51	.83	22.08
1868	....	....	....	....	....	....	.30	2.16	2.82	1.51	2.56	.75	20.16
1869	1.21	1.89	2.02	2.27	4.29	5.98	4.45	2.84	....	....	....	....	37.44
Means	2.67	2.16	2.43	3.36	3.61	3.13	3.68	3.21	4.20	2.44	3.35	2.65	36.23

TABLE XV.—TOLEDO.

Showing the Warmest and Coldest days for ten years; also, the Mean Temperature of the year, Yearly Range, Mean Temperature of the Warmest and Coldest days, with date, at Toledo, Ohio. By J. B. TREMBLY, M.D.

Years.	Maximum temperature.	Month and date.	Minimum temperature.	Month and date.	Mean temperature for the year.	Yearly range.	Mean temperature of warmest days.	Month and date.	Mean temperature of coldest days.	Month and date.
1860	94	Aug. 6th.	—10	Jan. 2nd.	49.343	104	83.	Aug. 7th.	—2.66	Jan. 2nd.
1861	96	Aug. 2nd.	— 4	Feb. 8th.	50.368	100	87.	Aug. 2nd.	9.66	Jan. 30th.
1862	97	July 6th.	— 2	Feb. 15th.	51.732	99	87.	July 6th.	11.66	Feb. 15th.
1863	95	Aug. 2nd.	6	Feb. 3d.	51.069	89	85.33	Aug. 2nd.	9.33	Feb. 3rd.
1864	98	July 28th.	—15	Jan. 1st.	49.987	113	87.33	June 25th.	—11.66	Jan. 1st.
1865	94	July 6th.	— 1	Jan. 11th.	49.639	95	82.66	June 6th.	5.66	Jan. 26th.
1866	95	July 16th.	—16	Jan. 16th.	47.994	111	85.66	July 16th.	—7.	Feb. 15th.
1867	94	July 23rd.	— 6	Jan. 14th.	48.819	100	80.66	July 24th.	6.	Jan. 29th.
1868	100	July 14th.	—10	Feb. 3rd.	47.761	110	87.33	July 14th.	4.	Jan. 9th.
1869	95	Aug. 20th.	3	Feb. 28th.	48.512	92	84.33	Aug. 19th.	11.66	March 6th.
	100	July 14th.	—16	Feb. 16th.	49.554	....	87.33	Aug. 14th.	—11.66	Jan. 1st.

SUMMARY FOR TEN YEARS.

The warmest year in ten years, was 1862, mean temperature	51.732
The coldest year in ten years, was 1868, mean temperature	47.761
The mean temperature for ten years	49.554
The mean temperature of the warmest day in ten years, July 14th, 1868	87.33
The mean temperature of the coldest day in ten years, January 1st, 1864	11.66
The highest temperature in ten years, July 14th, 1868	100.00
The least temperature in ten years, February 16th, 1866	—16.

TABLE XVI.—TOLEDO.

Showing the amount of Rain and Melted Snow, in inches, which fell during each month of the year, from January 1st, 1861, to December 31st, 1869; also, the mean for nine years, at Toledo, Ohio. By J. B. Trembly, M.D.

Month.	Melted Snow and Rain in Inches.									
	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	Mean for nine years.
January	2.125	3.875	2.875	.375	.75	1.75	1.5	1.25	1.6875	1.7986
February	1.375	2.875	3.562	.9375	1.6875	2.3125	3.125	1.0625	3.4375	2.2642
March	5.5	5.562	2.4375	1.9372	1.75	3.77	2.225	8.75	3.635	3.8502
April	5.75	4.437	1.875	4.75	3.125	.875	3.625	3.3755	4.8125	3.6249
May	4.677	6.	2.4375	2.1875	2.25	5.375	5.5	5.3125	5.75	4.3877
June	3.875	3.562	2.5	3.5	3.625	4.6875	1.9375	8.1875	8.25	4.4583
July	5.125	2.875	3.437	3.25	6.062	4.	2.0625	2.5	2.625	3.5594
August	3.363	2.375	2.213	4.211	3.75	2.4375	2.437	2.4375	.625	2.9844
September	2.562	2.375	1.625	7.006	10.1875	7.1875	2.	2.5	1.625	4.1186
October	2.312	2.25	3.125	1.6875	2.25	2.625	2.875	1.625	2.8125	2.3957
November	3.125	2.5	3.75	5.8125	.3125	3.125	2.	2.875	4.5625	3.1138
December	1.375	4.312	2.	1.5	3.5625	2.5625	1.875	1.062	2.4375	2.3629
Total	36.466	42.998	32.637	37.1545	39.312	40.6878	31.062	42.9375	42.25	38.9087

In 1868 there was the greatest amount of precipitation, and the least in 1867.

APPENDIX B.

PROFILES OF RAILROADS AND CANALS.

The subjoined partial profiles of our more important railroads and canal lines are published as matters of public interest, and to illustrate the description given of the topography of the State. They have been furnished by the officers of the several public works enumerated, or by the engineers who made the surveys, and form the most accurate data we have been able to obtain. It will be noticed, however, that only a few of our railroads are included in the list given, and that there are some discrepancies in the reported altitudes of intersecting lines. These errors of omission and commission are, however, of less moment from the fact that a much fuller representation of the local topography of the State will be given in the final volume of the Report of the Geological Survey, and before that shall be published the profiles of our railroads will be co-ordinated so as to eliminate some of the discrepancies to which reference has been made. But a small part of the material already on hand is now published, on account of necessary limitation of space.

J. S. N.

ALTITUDES OF STATIONS ON ATLANTIC AND GREAT WESTERN RAILWAY.

(Above Lake Erie.)

	Feet.		Feet.
Orangeville (State line)	370	West Salem	513
Berghill	483	Polk	667
Johnston Summit	553	Ashland	511
Baconsburg	390	Windsor	494
Warren	327	Mansfield	581
Leavittsburgh	322	Ontario	802
Braceville	326	Galion	596
Windham	389	Caledonia	493
Freedom	575	Marion	389
Summit	613	Berwick	345
Ravenna	520	Richwood	369
C. and P. crossing	522	North Lewisburg	507
Kent	474	Taylortown	518
Tallmadge	527	Urbana	454
Akron	430	Hunt's	379
New Portage	392	Springfield	335
Wadsworth	542	Sneider's	311
Seville	403	Kneisley's	230
Bridgeport	380	Dayton	179

MAHONING DIVISION A. AND G. W. RAILWAY.

Cleveland, A. and G. W. depot	24	Leavittsburg	322
Newburg	240	Warren	317
Plankroad	469	Niles	336
Solon	457	Girard	310
Aurora	515	Brier Hill	338
Mantua	536	Youngstown	290
Garrettsville	455	Beatch Mine	350
Windham	372	Hubbard	328
Braceville	340	State line	252

PITTSBURGH, FORT WAYNE AND CHICAGO RAILROAD.

Enon	434	Alliance	524
State line	472	Beach Creek	605
Palestine	455	Strasburg	526
Leslie's Run	479	Nimishillen Creek	574
New Waterford	503	Louisville	544
Bull Creek	515½	Nimishillen Creek	488
Columbiana	555	Canton	474
Mill Creek	534	Massillon	392
Beaver Creek	487½	Tuscarawas River	379
Green Creek	461	Massillon Mines	385
Green Creek Siding	454	Newman's Creek	439
Middle Fork	461	Fairview	451
Franklin	506	Orrville	499
Salem	620	Sugar Creek	469
Damascus	615	Wooster Summit	563
Smithfield	569	Apple Creek	369
Mahoning River	501	Wooster	342

	Feet.		Feet.
Killbuck	376½	Kirby	309
Shreves	352	Forest	365
Lakeville Road Crossing	381	Blanchard's Fork	327
Bridge over Lake Fork	375	Dunkirk	376
Loudonville	412	Washington	379
Perryville	433	Hog Creek Marsh	374
Bridge over Black Fork	410	Johnstown	383
Lucas	534	Lafayette	363
Mansfield	592	Hog Creek	288
Spring Mills Crossing	639	Lima	309
Richland Crossing	640	Elida	225
Crestline	594	Delphos	211
Leesville	562	Middle Point	211
Robinson	500	Van Wert	213
Bucyrus	434	Conroy	218
Nevada	359	Dixon	225
Broken Sword Creek	343	Monroeville	220
Edenville	355	Maples	230
Upper Sandusky	287	Fort Wayne	235

CLEVELAND, COLUMBUS, CINCINNATI AND INDIANAPOLIS RAILWAY.

Cleveland depot	10	Crawford and Richland line	548
" Superior street	32	Summit, near Crestline	604
Chestnut Ridge	168	Crestline	601
Berea	220	Galion	595
Olmsted	224	Crawford Co. line	585
Columbia	241	Iberia	573.32
Eaton	240	Gilead	466
Grafton	228	Cardington	437
La Grange	255	Delaware Co. line	405
Wellington	286	Ashley	412
Rochester	360	Eden	405
Huron Co. line	390.50	Delaware	378
New London	421	Berlin	381
Greenwich	475	Lewis Center	387
Salem	507	Worthington	340
Shelby	544	Columbus	170.80

INDIANAPOLIS DIVISION.

Galion	595	Bellefontaine	640
Marion	402	Sidney	383
Summit, 4 m. east of Bellefontaine	773	Union	532

COLUMBUS AND HOCKING VALLEY RAILROAD.

Columbus depot	170.80	Millville	174
South depot	144	Enterprise	170
Starch factory	165	Falls Mills	163
Edwards'	189	Logan	155
Groveport	164	Haydenville	116
Winchester	196	Lick Run	114
Carroll	240	Nelsonville	108
Lancaster	253	Salina	84
Sugar Grove	193	Athens	81

TOLEDO, WABASH AND WESTERN RAILROAD (TOLEDO TO FORT WAYNE.)

	FEET.
Toledo	10
Maumee City	66
White House	79
Washington	100
Liberty	109
Napoleon	107
Two Mile Creek	113
Prairie Run	127
Sand Hill	166
Defiance	125
Antwerp	157
Indiana line	172
New Haven	187
Summit	222
St. Mary's River	191
Divide	213

CINCINNATI AND MARIETTA RAILROAD.

Loveland	20.50
Spence's	254
Blanchester	404
Martinsville	470
Vienna	557
Leesburg	457
Walnut Creek bridge	405
Paint Creek	323
Buckskin	347
"	353
Frankfort	190
Paint Creek	165
" "	157
" "	154
Anderson	135
Chillicothe	62
Scioto bridge	52
Dry Run	84
Schooley's	93
Londonderry	52
Salt Creek	42
Pigeon Creek	53
Raysville	63
Pigeon Creek	80
Tunnel	125
Hamden	148
Raccoon Creek	135
Elk Fork of Raccoon Creek (Vinton Furnace)	138
Raccoon Creek	152
Zaleski	148
Big Sand Furnace	139
Moonville	150
Tunnel	150
Mineral City	153
Marshfield	253
Hocking River	85
" Canal	85
Athens	81
Warren's	98
Pilcher Grade	301
New England	235
Sharp's Run	206
Fisk's Tunnel	166
Herrold's Tunnel	145
Federal Creek	70
Big Run	83
"	71
Cutler	204
Big Poland	180
Little Hocking	182
Vincent's	201
Tunnel	240
Harmar	50

CLEVELAND AND PITTSBURGH RAILROAD.

Cleveland machine shop	56
" Euclid street avenue	95
Newburg	224
Mill Creek	210
Bedford	368
Tinker's Creek	248
" " below rail	120
Macedonia	420
Hudson Station	480
" Village	547
Cuyahoga River bridge	474
" " surface	456
P. & O. canal rail on bridge	509
" " surface	495
Ravenna Station	530
" Public Square	560
Rootstown	550
Summit in Atwater	603
Atwater	560
Lima	525
Beech Creek, rail	471
" " water	446
Alliance	516
Mahoning Summit	627
Bayard	503
Sandy Summit	612
Yellow Creek Summit	543
Salineville	306
Hammondsville	115
Linton, mouth of Yellow Creek	121
Wellsville	115
Liverpool	120
Smith's Ferry	125
Industry	125
Beaver	138
Sewickleyville	165
Allegheny, outer depot	191
Pittsburgh	172

TUSCARAWAS BRANCH.

	Feet.		Feet.
Bayard	503	Tunnel	446
Minerva	480	Mineral Point	386
Pekin	460	Zoar Station	314
Oneida	436	Canal Dover	307
Malvern	426	New Philadelphia	331
Waynesburg	426		

WHEELING BRANCH.

McCoy's	111	Portland	90
Sloan's	125	Martinsville	86
Steubenville	90	Bellaire	82

LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY.

State line	79	Monroeville	161
Conneaut	78	Bellevue	190.9
Pt. Amboy	123	Clyde	127.3
Kingsville	98.40	Fremont	61.93
Ashtabula	74.67	Genoa	65
Saybrook	77	Toledo	13.6
Geneva	94.16	Holland	66
Unionville	130.81	Ridge	113
Madison	141.83	Swanton	110
Perry	133.09	Delta	149
Grand River	87	Wauseon	200
Painesville	76	Summit	207
Mentor	76.80	Pettisville	188
Willoughby	61.80	Archbald	165
Wickliffe	83.70	Stryker	146
Northwood	69.40	Bear Creek	125
Euclid	53.70	Bryan	198
Cleveland depot	18.70	Melburn	270
" Superior street	32	Summit	304
Chestnut Ridge	168	Edgerton	270
Berea	220	Butler	297
Elyria	155	Waterloo	340
Oberlin	252	Lawrence	364
Townsend	336	Corunna	397
Norwalk	155.4	Summit	425

PITTSBURGH, CINCINNATI AND ST. LOUIS RAILROAD.

(STEUBENVILLE TO NEWARK.)

Washington street, Steubenville	155	Philadelphia Road	285
Mingo Station	94	Dennison	282
Gould's Station	106	Uhrichsville	290
Tunnel No. 1	260	Trenton	260
Smithfield	200	Lock 17	255
Tunnel No. 2	370	Port Washington	240
Reed's Mill	238	Newcomerstown	223
Skelley's Station	268	Oxford	220
Tunnel No. 3	490	West Lafayette	230
Bloomfield Station	328	Coshocton	198
Unionport	373	Rock Run	185
County line, Jefferson and Harrison	418	Conesville	165
Miller's	432	Adams' Mills	158
Cadiz Junction	518	Dresden	162
Tunnel No. 4	605	Frazeysburgh	178
Fairview	436	Nashport Road	200
New Market	386	Hanover	257
Mastersville	363	Montgomery's	227
Tunnel No. 5	480	Newark	246

SANDUSKY, DAYTON AND CINCINNATI RAILROAD.

	FEET.		FEET.
Sandusky	25	Kenton	442
Bellevue	186	Bed of Scioto	380
County line	207	County line, Logan and Hardin	484
Lodi	282	North Fork, Big Miami	466
Republic	308	Bellefontaine	643
Tiffin	183	West Liberty	526
Carey	245	Urbana	458
Cranberry Marsh	356		

DAYTON AND MICHIGAN RAILROAD.

FROM H. F. HARTWELL, CHIEF ENGINEER.

	Above low water in Ohio.	Above Lake Erie.
Cincinnati	66	.....
Hamilton	162	29
Dayton	313	180
Dayton, canal	299	166
Troy	403	270
Piqua	493	360
Sidney	561	428
Principal summit	613	480
Anna	578	445
Botkins	574	381
Wapakoneta	451	318
Cridersville	447	314
Lima	435	302
Sugar Creek	405	272
Cairo	374	241
Columbus Grove	327	194
Ottawa	288	155
Leipsic	321	188
Belmore	292	159
Alma	270	137
Milton	250	117
Weston	241	108
Montgomery	227	94
Perrysburgh	197	64
Toledo	145	12

PROFILE OF OHIO CANAL.

(*Above Lake Erie.*)

(CLEVELAND TO ROSCOE.)

Cleveland, lock 44, surface of water	13.33	Lock 30	118.66
Lock 43	20.66	Lock 29—Peninsula	129.66
Lock 42—removed	....	Lock 28	141.66
Lock 41	24.66	Lock 27	151.66
Lock 40	31.66	Lock 26	156.66
Lock 39	40.66	Lock 25	166.66
Lock 38	47.66	Lock 24	176.66
Lock 37	55.66	Lock 23—Yellow Creek	184.66
Lock 36	62.66	Lock 22—Old Portage	192.66
Lock 35	72.66	Lock 21	200.66
Lock 34	82.66	Lock 20	208.66
Lock 33	90.66	Lock 19	218.66
Lock 32	98.66	Lock 18	228.66
Lock 31	108.66	Lock 17	237.66
		Lock 16	248.66

	FEET.		FEET.
Lock 15	258.66	Lock 7	341.66
Lock 14	268.66	Lock 8—Bolivar	333.66
Lock 13	278.66	Lock 9	325.66
Lock 12	288.66	Lock 10—Zoar Mills	319.66
Lock 11	298.66	Lock 11	312.66
Lock 10	308.66	Lock 12—Dover	305.66
Lock 9	318.66	Lock 13—Lockport	293.66
Lock 8	328.66	Lock 14—Newcastle	285.66
Lock 7	336.66	Lock 15—Trenton	275.66
Lock 6	346.66	Lock 16 "	267.66
Lock 5	366.66	Lock 17—Gnaddenhutten	256.66
Lock 4	368.66	Lock 18—Port Washington	250.66
Lock 3	376.66	Lock 19	240.66
Lock 2	386.66	Lock 20	233.66
Lock 1—Summit Level	396.66	Lock 21—Newcomerstown	226.66
Lock 1—South end of Summit		Lock 22	219.66
Level	395.66	Lock 23	212.66
Lock 2	387.66	Lock 24	204.66
Lock 3	379.66	Lock 25	195.66
Lock 4	372.66	Lock 26—Double—Roscoe	181.66
Lock 5—Massillon	366.66	Lock 27	171.66
Lock 5a "	360.66	Lock 28 Adams' Mill	161.66
Lock 6—Navarre	350.66	Lock 29	151.66

PROFILE OF THE MIAMI CANAL.

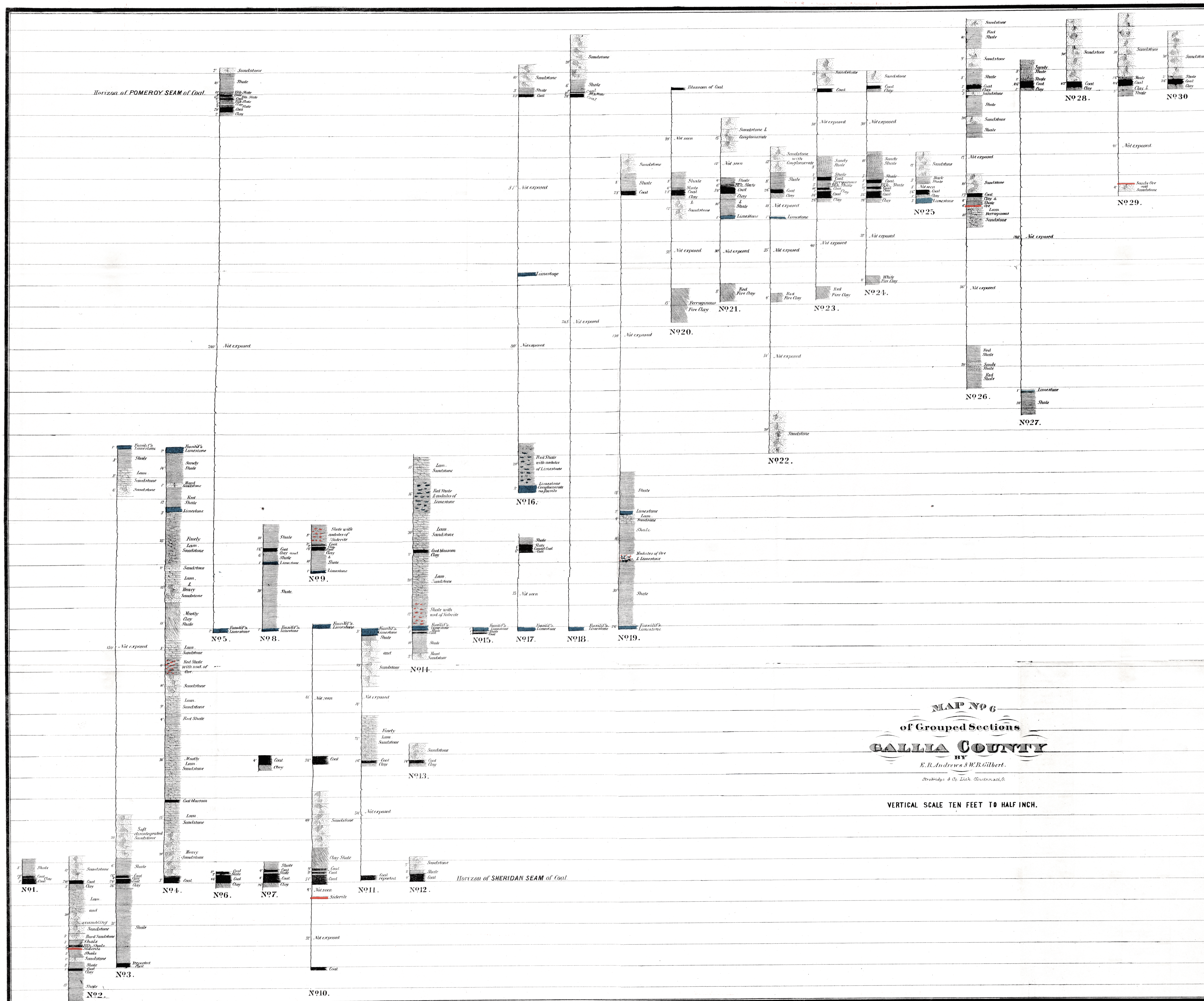
Junction	147.25	Lock 13—St. Mary's	291.25
Lock 32	152.75	Lock 12	299.50
Lock 31	156.75	Lock 11	306.50
Lock 30	162.75	Lock 10	313
Lock 29	167.75	Lock 9	319
Lock 28	177.25	Lock 8	331
Lock 27	182.25	Lock 7	336
Lock 26	189	Lock 6	345
Lock 25	196.50	Lock 5	354
Lock 24	202	Lock 4	361
Lock 23—Delphos	211	Lock 3	367.50
Lock 22	219.25	Lock 2	377.50
Lock. 21	224.25	Lock 1—Bremen Summit	386.50
Lock 20	231.50	Near Sidney	376.00
Lock 19	240	At Troy	257
Lock 18	246.75	D. and M. R.R. crossing, Dayton	166
Lock 17	255.75	Basin at Hamilton	37
Lock 16	263.50	Upper level of Canal at Cincinnati	23
Lock 15—Spencerville	274	Low water in Ohio at Cincinnati	133
Lock 14	283		

PROFILE OF THE WABASH CANAL.

(FROM TOLEDO TO STATE LINE.)

Lock 1—Toledo, surface of water	7	Lock 1—Defiance	96.5
Lock 2 "	15	Lock 2 "	105.5
Lock 3 "	22.5	Lock 3	114.5
Lock 4 "	31.5	Lock 4	123.5
Lock 5 "	39.5	Lock 5	130.5
Lock 6	48.5	Lock 6	137.5
Lock 7	55.5	Lock 7	142.5
Lock 8	61.5	Lock 8	147.25
Lock 9—Providence	63.5	Lock 9	152.25
Lock 10	73.5	Lock 10	158.25
Lock 11	81.5	Lock 11	163.25
Lock 12—Texas	88.5	Lock 12	171.25
Lock 13—Independence	88.5	Lock 13—abandoned	171.25

INDEX TO VOLUME I., PART I.


MAP No 6
of Grouped Sections
GALLIA COUNTY
BY
E. B. Andrews & W. B. Gilbert.
Strobridge & Co. Lith. Cincinnati, O.
VERTICAL SCALE TEN FEET TO HALF INCH.
Horizon of POMEROY SEAM of Coal
Horizon of SHERIDAN SEAM of Coal
No 1.
No 2.
No 3.
No 4.
No 5.
No 6.
No 7.
No 8.
No 9.
No 10.
No 11.
No 12.
No 13.
No 14.
No 15.
No 16.
No 17.
No 18.
No 19.
No 20.
No 21.
No 22.
No 23.
No 24.
No 25
No 26.
No 27.
No 28.
No 29.
No 30
Not exposed
Not seen
Blossom of Coal
Fossiliferous Limestone
Sandstone
Shale
Coal
Clay
Limestone
Siderite
Red Fire Clay
Ferruginous Fire Clay
White Fire Clay
Sandstone & Conglomerate
Red Shale with nodules of Limestone
Limestone Conglomerate no fossils
Sandy Ore and Sandstone

MAP No 7
of Grouped Sections
MEIGS COUNTY
BY
E.B. Andrews & W.B. Gilbert.
VERTICAL SCALE TEN FEET TO HALF INCH.
Horizon of POMEROY SEAM of Coal
Horizon of AMES LIMESTONE
No 1
No 2
No 3
No 4
No 5
No 6
No 7
No 8
No 9
No 10
No 11
No 12
No 13
No 14
No 15
No 16
No 17
No 18
No 19
No 20
No 21
No 22
No 23

MAP No 8
of Grouped Sections
ATHENS COUNTY
BY
E. B. Andrews & W. B. Gilbert.
Strobridge & Co. Lith. Cincinnati, O.
VERTICAL SCALE TEN FEET TO HALF INCH.
Horizon of CUMBERLAND SEAM of Coal
Horizon of POMEROY SEAM of Coal
Horizon of AMES LIMESTONE
Horizon of SHERIDAN or BAYLEY'S RUN SEAM of Coal
Horizon of NELSONVILLE SEAM of Coal
Pitcher Tunnel
No 1
No 2
No 3
No 4
No 5
No 6
No 7
No 8
No 9
No 10
No 11
No 12
No 13
No 14
No 15
No 16
No 17
No 18
No 19
No 20
No 21
No 22
No 23
No 24
No 25
No 26
No 27


Top of High Hill
Horizon of CUMBERLAND SEAM of Coal
Horizon of Ames Limestone
Horizon of SHERIDAN or ALEXANDER SEAM of Coal
Horizon of Nelsonville seam of Coal
MAP No. 10
of Grouped Sections
MUSKINGUM COUNTY
South of Central Ohio R.R.
E. B. Andrews & W. B. Gilbert.
Strobridge & Co. Lith. Cincinnati, O.
VERTICAL SCALE TEN FEET TO HALF INCH.


Horizon of CUMBERLAND SEAM of Coal
Horizon of POMEROY SEAM of Coal
Horizon of AMES LIMESTONE
No 1
No 2
No 3
No 4
No 5
No 6
No 7
No 8
No 9
No 10
No 11
No 12
No 13
No 14
No 15
No 16
No 17
No 18
No 19
No 20
No 21
No 22
MAP No 9
of Grouped Sections
MORGAN COUNTY
BY
E. B. Andrews & W. B. Gilbert.
Strobridge & Co. Lith. Cincinnati, O.
VERTICAL SCALE TEN FEET TO HALF INCH.